# R&D

## Research & Development

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R D

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# Japan's Open Door: Is the U.S. Missing Its Golden Opportunity?

Japan has opened its new superconductivity lab to outsiders, but U.S. companies are ignoring the invitation.

*By **Robert Cassidy**, Senior Editor, Business, R&D magazine*

JUST A MONTH AGO, Prof. Shoji Tanaka of Tokyo Univ., the physicist who, over the past 13 years, has led Japan to supremacy in semiconductors, fiber optics, and optical disks, opened the doors of a state-of-the-art research laboratory at Tokyo's International Superconductivity Technology Center (ISTEC).

After the opening ceremonies, dozens of researchers from 45 Japanese companies began studying and developing high-temperature superconductive (HTS) materials.

The creation of the ISTEC lab is viewed by some observers as defining a new role for Japan, not only in science and technology, but in foreign relations as well. They see in Japan's superconductivity initiative a chance for that nation to become a world-class leader in basic research, much as it has dominated consumer electronics in the past two decades.

Japan watchers also view the HTS program as concrete evidence of the country's policy of *kokusaika*, or internationalization. Japan is determined to change its image abroad from that of a nation respected for its ability to exploit the research of others, to that of an intellectual superpower capable of opening new frontiers of scientific investigation and magnanimously sharing the fruits of that research with others.

"Japan is in the process of redefining its role in the world," says Martha Harris, head of the National Research Council's Japan Office. "In years past, there has been criticism of Japan as a country that absorbed technology and flourished in the marketplace, but which did not pass its knowledge back to the rest of the world. *Kokusaika* is an attempt to define a new role, putting more resources into science and technology and opening up those resources to others."

For the U.S., the opening of the ISTEC lab is notable for yet another reason: No American scientists are working there, despite an invitation to foreign companies to peer through the *madoguchi*, or window, onto Japan's HTS research. Three U.S. companies—DuPont, IBM, and Rockwell Intl.—have joined ISTEC as junior partners but are not doing research in the new lab.

Corporate America's decision to reject Japan's invitation to participate in joint research raises an important policy question: Why, after years of complaining that the Japanese have been "stealing" their research, are U.S. companies unwilling to join hands with them on what could be one of

## With no payoff in sight, American industry has done well to resist the temptation to pour money down a rathole.

the most profitable new technologies in postwar history—especially when knowledgeable sources such as the Federal Office of Technology Assessment (OTA) are saying that U.S. companies already may have fallen behind the Japanese in HTS research?

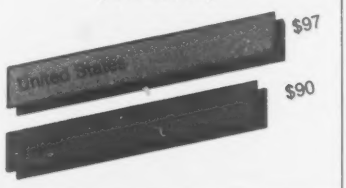
From interviews with researchers, business executives, and Japanologists, a clear but disturbing explanation begins to emerge as to why American firms are snubbing Japan's offer to cooperate on HTS research. The reasons range from Yankee caution to outright xenophobia, with a touch of hubris thrown in for good measure.

### Practical matters

One barrier to U.S. involvement in ISTEC is the cost—for full members, about $800,000 to pay for the lab construction, another $90,000 a year in dues. The three U.S. firms involved have signed up at a lower level, about $16,000 to join and an equal amount in annual dues. That's supposed to provide them with a newsletter and admittance to a few meetings, but not access to the lab. This compares to the 90 Japanese firms that have joined ISTEC, half of them at the full price.

DuPont sees junior membership as a must. "If you're an international organization like DuPont, you have to do it," says spokesman Alan Lauder. The company has 220 employes, almost all Japanese, at its Yokohama

**Corporate support of HTS research, 1988**
**(in millions)**




*Why go to Tokyo, asks Schmitt, when you can go to Houston?*

technical facility. "We're not faced with the problem of having to learn the culture, but there are not a great number of U.S. corporations that have a presence like that in Japan," he says.

"We joined at the low price, which gives us access [to the newsletter and meetings], but where we don't have to play scientist," says Lauder. "We certainly didn't think it was worth the full price. We'll make a decision about that later on."

Rockwell Intl.'s chief scientist says his company is optimistic, but cautious, about joining ISTEC. "The majority of our business addresses global markets, and our R&D must be international as well," says Peter Cannon. "It would be a Greek tragedy, with *hubris* writ large, if we thought we could do it all by ourselves." Rockwell has a number of joint ventures in Japan, including one with Mitsubishi.

IBM, which has a separate division in Japan, would say only that junior membership "best suits our business needs."

But many more have balked at the hefty tab. "This past spring, I asked Dr. Tanaka himself what you get for joining, and I don't think it was clear even to him," says Bellcore's assistant vice president John M. Rowell. "At that price, it's a pretty expensive newsletter." Besides, he says, "the research will be in the pre-emptive stage, so it will probably be published in the open literature."

Rowell notes that full members also must absorb the cost of sending one or two scientists—who are fluent in Japanese, no less—to work at the ISTEC lab. "I would have picked a site other than Tokyo," he says. "The cost of living there is impossible, so you have to commute two hours to get to work."

Former General Electric research chief, now president of Rensselaer Polytechnic Inst. (Troy, NY), Roland Schmitt feels that the Japanese failed

### Who's ahead in the race for superconductivity?

IT'S NOT SUPPOSED to be asked, but whenever researchers talk about superconductivity, the question gets raised anyway: Who's ahead, the U.S. or Japan?

To some, it's a moot point, since commercial application is so distant. Rockwell Intl. chief scientist Peter Cannon says it likely will take the equivalent of 1,000 world-class scientists working "several years" before any breakthrough occurs.

Setting aside the argument that, as a spokesman for IBM phrased it, "nationalism is not the issue," how are the two nations deploying their forces? And what does that say about who's likely to come out on top in the race for HTS supremacy?

According to the Congressional Office of Technology Assessment, the Japanese government will spend about $70 million this year on superconductivity research, working through four ministries: the Ministry of International Trade & Industry (MITI), whose projects include the ISTEC program; the Science & Technology Agency (STA), whose New Superconductivity Materials Research Assn. is, like ISTEC, open to foreigners (although no U.S. companies have joined); the Ministry of Education (Monbusho), which supports university research much as the U.S.'s NSF does; and the Ministry of Transportation, which is helping to finance a magnetically levitated train project.

In private industry, at least 38 firms were spending about $90 million and had 900 scientists, engineers, and technicians at work on both low- and high-temperature superconductivity as of the early part of this year, the OTA says.

The U.S. government will devote $95 million to HTS alone in 1988, the bulk of it for the Depts. of Defense ($46.0 million) and Energy ($27.2 million). NSF will get $14.5 million, NASA $4.2 million, NIST (formerly NBS) $2.8 million, and the Bureau of Mines $100,000.

OTA says that 55 U.S.-based companies have about 625 researchers working on both LTS and HTS. They will spend $97 million in corporate funds this year.

Roughly speaking, the resources

to sell U.S. companies on ISTEC's benefits. "They have to do a lot more marketing, and perhaps start a little more modestly [in cost]," says Schmitt.

Another reason why American companies have not joined Japan's HTS initiative, he says, is that they have plenty of opportunities for research partnerships in the U.S. Why go to Tokyo, Schmitt asks rhetorically, when you can go to Houston?

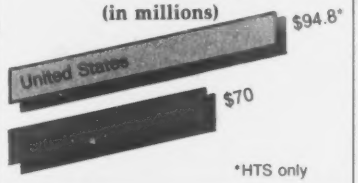
"Besides, U.S. firms have a lot of experience working with American universities, and they know what to expect," says Schmitt. "We don't have that kind of experience working with Japanese institutions, so there's more risk."

Schmitt also would like to see the Japanese change some of their rules. "People talk about reciprocity between the U.S. and Japan, but reciprocity doesn't mean symmetry," he says. "For an American firm to get something out of ISTEC requires a much greater level of commitment than it does working with a U.S. program. It took the Japanese years and years to learn how to extract science from us, and now that they may have something for us to draw out, it's ridiculous for them to expect Americans to learn how to do that overnight."

Finally, there are those who say caution is advisable because commercialization is so far down the road. "There's no payoff in sight," says Prof. Rustum Roy of Pennsylvania State Univ. "Unless this particular technology brings some enormous economic advantage, it's not going to cut it with business.

"The Europeans are taking a wait-and-see position, and American industry has done well to resist the impulse to pour money down a rat hole." Roy says he favors sending researchers to foreign countries when the possibility of commercialization looks more promising.

**Government support of superconductivity research, 1988**
**(in millions)**




*The Japanese are widely mistrusted, says an R&D executive.*

"The managers of U.S. companies have been astute enough to see that an HTS product is not just around the corner, so why get involved with Japan?" adds Harry Kroger, a former Sperry researcher now with the Microelectronics & Computer Technology Corp. (MCC) in Austin, TX. MCC has a $1.3-million HTS effort under way, involving more than a dozen U.S. companies. "ISTEC is a monster-sized effort, but I don't know if it will succeed," he says. "It's based on a lot of faith."

Some knowledgeable observers say they are disturbed that more U.S. companies are not taking a gamble with ISTEC. "If you're really committed to doing work at the state of the art, then you want to know what others are doing," says Richard Samuels, director of MIT's Japan Science and Technology Program. "That's what the Japanese mean by *madoguchi*. It's a window of opportunity."

### A hidden agenda?

Yet another reason U.S. firms are passing up Japan's invitation to share HTS research may be that it looks too good to be true. "The Japanese are widely mistrusted," says a chemical-industry executive. "They give nothing and get what they can out of you. There's lots of skepticism as to their sincerity about sharing technology."

An oil-company researcher who has worked in Japan says, "I don't believe

being devoted by each country appear comparable. A few individuals feel that the U.S. has the edge. A survey of 51 U.S. electronics firms by *Electronic Business* magazine revealed that the majority of computer executives believe the U.S. is clearly ahead.

In "Commercializing High-Temperature Superconductivity," its recent report on the subject, OTA states—in bold type—that "American companies may already have begun to fall behind."

OTA says that, while a few major U.S. corporations—it mentions IBM, AT&T, and DuPont—are mounting "substantial efforts," too many others have taken a wait-and-see attitude. "They plan to take advantage of developments as they emerge from the laboratory—someone else's laboratory—or buy into emerging markets when the time is right," says the report.

Such strategies have not worked in recent years, the OTA says. Japanese companies, in contrast, see HTS as "a major new opportunity," and are willing to take greater risks to exploit that opportunity than are their American counterparts.

"The Japanese have the cash to exploit any discoveries, no matter where they are made," says the DOE's Ianniello. "With a few exceptions like IBM, most U.S. companies are not in the position of looking beyond a few years."

"We're spending more money, but you don't see any clarity of objectives," says OTA's John Alic. The bulk of the Federal dollars are going to national laboratories and universities, which Alic says "don't have a good track record of successful technology transfer."

But Bellcore's John M. Rowell says he doesn't agree with those who say the U.S. already has lost the race. "Dr. Tanaka told me that *they* feel they have to keep up with *us*," says Rowell.

So who's winning? Right now, it's probably anybody's game. Victoria Nerenberg, of the Superconductor Applications Assn., says "the true competition will be lab to lab, company to company, regardless of national boundaries."

But no matter what, says DuPont's Alan Lauder, "The benefits are going to come to those who are in it for the long haul, and with deep pockets." Whether they will be Japanese or American remains to be seen. □

**If you decide not to join Japan's HTS effort, make sure it's not because of scientific arrogance, says MIT's Samuels.**

it's a new dawn. My experience is that they say they want to work with us, but what actually happens is quite different. I don't think Japan is going to turn over a new leaf in its dealings with the rest of the world, certainly not as HTS gets closer to commercialization."

"There's a lot of showmanship to this," says Louis Ianniello, of the U.S. Dept. of Energy. "They're tough competitors, and I wonder how much they're going to just give away."

Victoria Nerenberg, director of the California-based Superconductor Applications Assn., says the Japanese "want to create an open-door policy so that they can't be accused of stealing our technology."

"I don't believe there are any hidden motives," says MCC's Kroger. "I have not found them to be devious. When I visit a Japanese lab, they're extremely open—more open than Americans are to their competitors. They're tight when it comes to things close to product, but so are we."

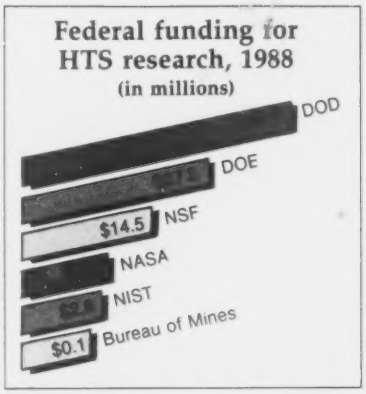
"We've had good relations with the Japanese," says Bellcore's Rowell. "I suspect that many of my people would rather work in Japan than in America, because there's more competition between U.S. companies. Try getting information out of AT&T."

"They're damned if they do and damned if they don't," says MIT's Samuels. "They're accused of either getting a free ride or of having a hidden agenda."

Some blame the ignorance—or myopia—of American business executives. "Most American companies have no idea of how to do business in Japan," says a chemist with experience working in Japan. "They view the Japanese as cut-throat, but that perception is driven by fear or repugnance toward the Japanese culture, not reality."

Americans would do better to learn from the Japanese, he says. "The Japanese are better at information gathering than we are, but I don't fault them for that," he says. "I do it when I'm visiting another lab, and I don't see it as unethical. If you're careless, the Japanese will exploit you to the fullest. You have to know what you're doing when you deal with them."

By not joining ISTEC, U.S. firms may be missing out not only on the lastest information about how to exploit superconductivity, but also on what their Japanese competitors and the government ministries are doing. The Japanese themselves see this "watchdog approach" as one of the main reasons to participate. As NEC vice president Michiyuki Uenohara told the *Wall Street Journal*, "Those by-products are more important to us than the technology itself."




*U.S. business may pay a price for ignoring this opportunity.*

Yet everyone in the superconductivity game realizes that at some point the door could get slammed shut. "The closer we get to commercial application, the more reluctant people will be to talk about what they're doing," says DuPont's Lauder.

### Overcoming pride

Despite the $60-billion trade imbalance Japan holds over the U.S., too many American firms prefer to go it alone, avoiding opportunities like Japan's HTS initiative. "There's still that 'if it's worth doing, we'll do it ourselves' attitude," says an American research director.

There are those who see the HTS invitation as a device for the Japanese, who view themselves as weaker than their American counterparts in basic research, to seduce the U.S. into "giving away" its research. "They have a rigid, bureaucratic research sector, especially in the universities," says the OTA's John Alic. RPI's Schmitt notes that "they have a few stars like Tanaka, but they don't have the depth of our university system."

"They realize that most of the fundamental breakthroughs have come from the West, and they need the synergism of having some of the main U.S. firms involved," an R&D executive says. "They have a need, and they're responding to it. They're not acting out of altruism."

But others say that American businesses may pay the price for ignoring openings like the ISTEC program with even greater declines in their global competitiveness. "U.S. companies think they're only competing against themselves when they're really competing against the whole world," says Bellcore's Rowell.

"If I were an adviser to American businesses, I would tell them not to lose an opportunity to have access to Japan's efforts," says MIT's Samuels. "Those may be bargain-basement prices. And if you come to a decision not to join the Japanese effort, make sure it's not because of scientific arrogance. The firms that are interacting with the Japanese, in Japan, are going to benefit in the long run."

Will Japan's HTS initiative succeed in producing the breakthroughs, both scientific and political, it is designed to achieve?

"I think we should expect to wait some time before the full implications of what's happening are felt," says NRC's Harris. "It will take a number of years for attitudes to change.

"For Japan, superconductivity has become a test for these new challenges, challenges that are broader than the science and technology issues themselves," adds Harris. The experimentation that is under way, both in the lab and in world politics, will be "of great interest to those who are watching Japan because it could be indicative of what's going on in the whole culture."

It should, she says, "be exciting to watch." **R&D**

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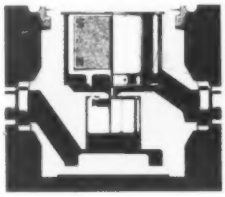
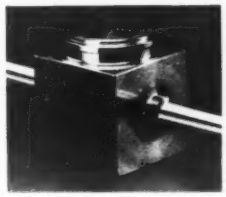


**Poppet** *Senses failure and snaps shut the instant flow increases. Leak-tight shut-off is maintained until re-set.*



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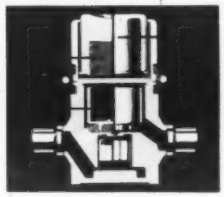

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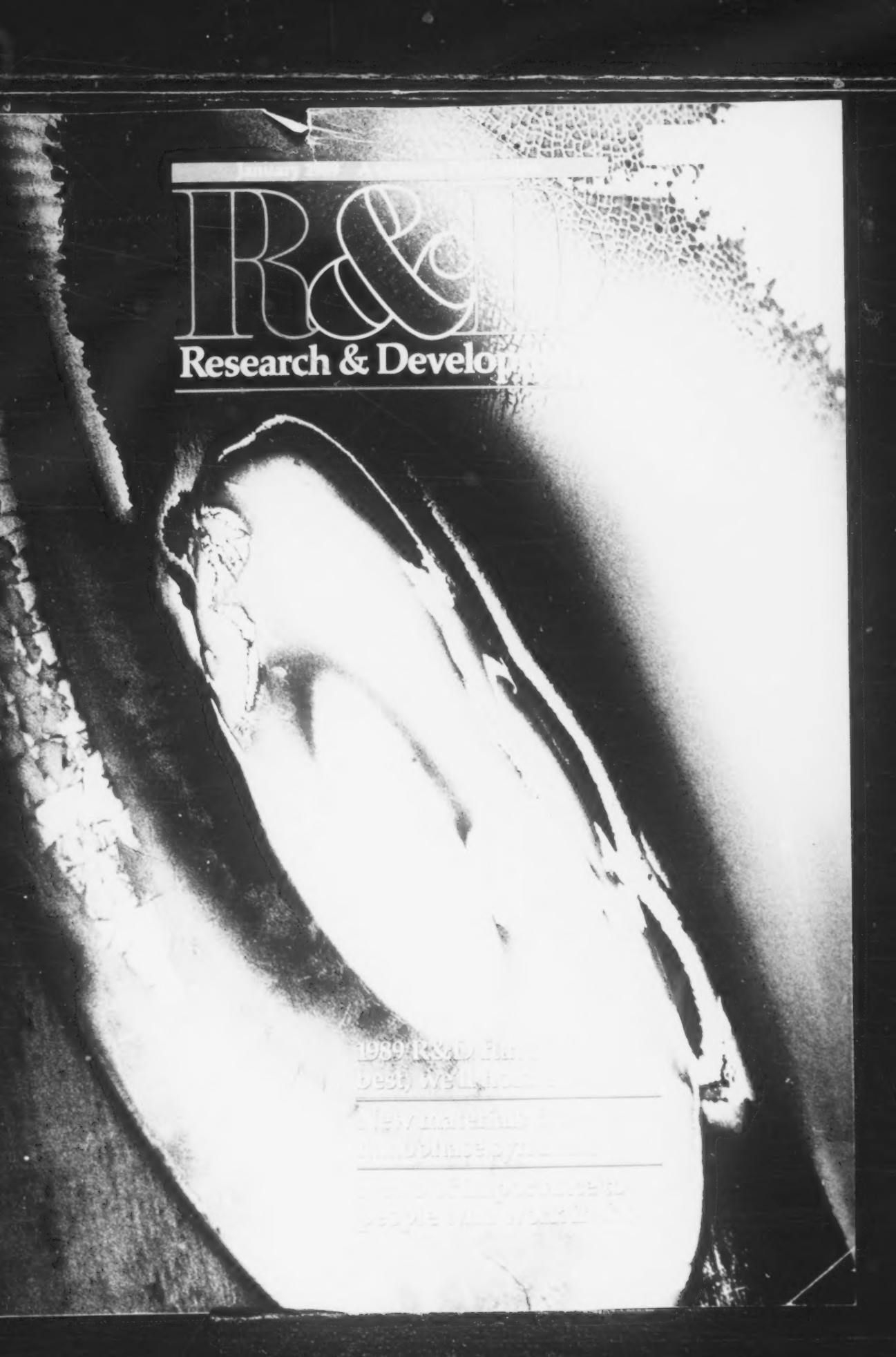
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***Nanophase $TiO_2$ powders** are collected on the cold finger in a synthesis chamber prior to consolidation in a process developed by researchers at Argonne National Laboratory (see page 56).*

INTERNATIONAL JOURNAL OF RESEARCH, DEVELOPMENT, AND QUALITY ASSURANCE

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# Research Funding for 1989 Won't Even Reach $131 Billion

The downturn in R&D's rate of growth that started in 1986 has taken its toll on this year's research spending.

*By **Robert Cassidy**, Senior Editor, Business, R&D magazine*

A FUNNY THING happened on the way to 1989: The bottom dropped out of R&D funding growth. The open spigot that poured out double-digit spending surges in the early 1980s seems to have been shut off about 1986, apparently more tightly than anyone thought.

For the past three years or so, in fact, the real total of dollars spent nationwide on R&D has been significantly less than was forecast.

The result: R&D funding, which was supposed to have hit $132 billion in 1988, fell well short of that mark and likely will not reach it even this year. The best that can be expected for 1989 is total R&D funding of less than $131 billion. What happened?

### Unexpected drop

Around 1986, the rate of growth in R&D funding apparently started tapering off, throwing off the projections from *R&D* magazine and the National Science Foundation (NSF).

For calendar year 1987, *R&D* magazine projected funds for research and development of $125 billion. Later, we downgraded that prediction to $123.6 billion.

Based on recent information from government sources, it is more likely that the 1987 figure was closer to $118 billion. That's a difference of 4.5% from our revised prediction.

A year ago, we said R&D funding would hit $132 billion in 1988, an increase of 6.8% over our revised 1987 prediction of $123.6. Later, we reduced our 1988 forecast slightly to put it in line with NSF's forecast, to $131.6 billion, a 6.5% increase over our revised '87 prediction.

Due to the lower base and the declining rate of change, however, the 1988 dollar figure probably also was too high, although the rate of change was reasonably accurate. The best available figure for 1988 R&D funding is $125 billion, a 5.9% increase over the probable 1987 total of $118 billion.

For 1989, *R&D* magazine projects funding of $130.8 billion for research and development, a 4.6% increase over the revised 1988 figure. In constant dollars, that means real R&D funding will decline (if you use the Cahners Economics Dept. figure of 5.0% for the Consumer Price Index) or will grow slightly (if you use the Office of Management & Budget's figure of 3.9% for 1989).

Industry will contribute $64.1 billion (49.0%) of that total, with the Federal government kicking in $61.1 billion (46.7%), and universities, colleges, and other nonprofit organizations adding $5.6 billion (4.3%). That's a drop of nearly two percentage points in the Federal portion and a nearly one-point boost in the university-nonprofit sector.

Once again, industry will actually carry out the bulk of the research, $93.8 billion worth (71.7%), a one-point drop in the portion it usually performs. Federal laboratories will conduct $14.8 billion in research (11.3%), also about a point less than their usual share. The universities and nonprofit organizations will perform $22.2 billion (17.0%)—a nearly two-point increase in that sector's "share of market," a trend we noted last year.

"The mix is changing a little," says Dr. Joseph Saloom, senior vice president of M/A Com Components Inc., Burlington, MA. "Industry is funding a lot more joint ventures with universities, so somewhat more of the research is actually being done at the universities."

### Economy flattening

From industry's point of view, the slide in R&D growth can be explained in one phrase: slower economic growth. As Cahners senior economist Madeline Franchi explains in the accompanying story, the six-year run-up of sales and profits that fueled R&D growth earlier in the decade definitely has tapered off.

Franchi predicts a mild letdown, with the GNP up just 2% in 1989, compared to the 4% annual growth we've been seeing. In fact, GNP growth in the third quarter of 1988 (the most recent available figure) was 2.2%. Slower economic growth usually means less growth in R&D.

"I don't get the feeling that there's going to be any kind of big splurge," says Dr. Jules Blake, vice president of research at Colgate-Palmolive.

There were other signs that R&D spending was in trouble:

• In its "R&D Scoreboard" last June, here's how *Business Week* described the "perilous cutback" in research spending:

"With the U.S. under escalating pressure from competitors, an R&D slowdown couldn't happen at a worse time," the magazine said. "But a wave of corporate restructuring and a continuing emphasis on short-term profits are pushing R&D spending back into the doldrums of the mid-1970s. Without question, R&D's days as a

## One theory holds that mergers and acquisitions have a chilling effect, forcing management to cut research budgets.

sacred cow are over for now."

• An *R&D* magazine poll of CEOs at the U.S.'s 476 largest industrial companies revealed that most of the firms' R&D budgets would not be growing as fast in the next three years as they had in the previous three years.

• The Industrial Research Institute, in a survey of 161 R&D directors, found that R&D funding as a percentage of sales will drop from 3.1% in 1988 to 3.0% in 1989.

### Gobbling up 'Velveeta'

As 1988 drew to a close, mergers and acquisitions continued to animate the corporate world, most recently the food sector. Pillsbury and RJR Nabisco were put in play. Kraft, the biggest R&D spender in the food business (nearly $63 million in 1987), was purchased by Philip Morris's General Foods division last October for $12.9 billion.

General Foods management said it anticipated no major changes for the merged companies, but those kinds of promises can't always be kept. "When we sold our Kendall paper division, the new ownership put the R&D director out of a job," says Colgate-Palmolive's Blake.

There are two schools of thought about the effect of takeovers on R&D spending. No one yet knows which is correct.

One theory holds that the threat of a takeover is usually so nebulous that most companies (and their research departments) go right on with business as usual until confronted with a real threat.

The other, more popular, theory holds that takeovers have a chilling effect, forcing management to trim research budgets in order to inflate the stock price and deflect unfriendly suitors.

Whether the Bush Administration will propose controls on takeovers, such as eliminating the deductibility of interest in leveraged buyouts, remains to be seen.

Looking closely at key industry groups, biotechnology firms will almost surely have to continue to spend high proportions of revenues on R&D. But diversified chemical companies like Du Pont and Monsanto, which have poured millions into biotech in recent years, may have to retrench on their investment, as the rewards of biotechnology research appear to be slower in coming than had been hoped for.

In the chemicals field, "companies will be spending on anything to do with new high-performance materials—plastics, ceramics, separations," says Frederick Levitt, director of government science relations for Dow Chemical. Composites, especially for the automobile industry, also are hot, he says.

Industrial machinery and electronics may be a little weaker in '89, Franchi notes, but the slowdown should be short-lived.

Certain industries, notably petroleum, have been paralyzed by global

## As the economy slows, so will R&D growth

FOR MANY INDUSTRIES, R&D funds as a percentage of net sales have been fairly consistent over the past few years. As sales and profits go, so does R&D spending. A notable exception: the electronics industry, where the need to keep up with fast-breaking technology has required that extra capital be devoted to R&D.

Since revenues generally follow the ups and downs of the economy, you will want to watch certain key indicators within the larger economic picture that can influence your R&D staffing and equipment budget.

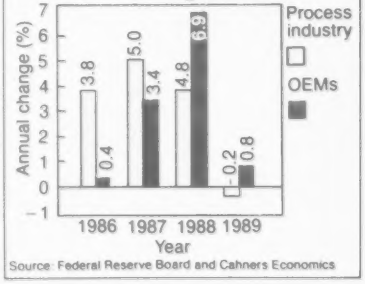
The Cahners Economics look ahead: slow going, but no big bust.

### Cooling down

After a six-year run, the economy is set for a relatively short and mild cooling-off period in 1989. The outlook includes a minor decline in GNP in the middle two quarters of the year, with the economy edging up to 2% growth for the year. That is below the 4% pace we've been seeing in recent years, but it is hardly a long-term recession.

Part of the slowdown is due to the flattening of purchases of durable goods by consumers. More fundamentally, the reversal can be attributed to the very sectors that prompted a faster pace of growth earlier in 1988—namely, trade and business investments in plant and equipment.

**Process and OEM industries' production**




Source: Federal Reserve Board and Cahners Economics

With a flame under the country's economy in 1988, utilization of current manufacturing capacity increased. Manufacturers got busy adding new capacity and modernizing existing facilities. Total spending for new plants and equipment soared 11.3% in 1988, to $162.3 billion.

The process industries, in particular, geared up to take advantage of the renewed domestic and foreign demand for their products.

However, spending on new plant and equipment will flatten in 1989. Total spending will decline to $161.1 billion this year, with most industries edging downward. The paper, petroleum, fabricated metals, motor vehicle, and aircraft industries are forecast to make small increases in their expenditures.

To understand what is happening, take a look at the process industries.

In 1988, the market for industrial materials experienced spot shortages and higher prices. Plant capacity utilization rates were exceptionally high in the process industries, and Cahners lead-times index (an index of average delivery times for 100 industrial materials) reached levels not seen since 1985.

Although tight supplies are typical toward the end of an economic expansion, supply bottlenecks were made worse by increased foreign demand for U.S. industrial materials and by domestic economic strength in the wake of 1987's stock market crash.

economics. With crude at $12.50 a barrel in Texas, says Amoco Oil's R&D director, Dr. Keith McHenry, "nobody's going to be spending a lot on R&D in our business."

### Washington cautious

According to sources who monitor Congressional appropriations, real R&D funding through Sept. 30, 1989, looks something like this:

Defense, $37.742 billion; National Institutes of Health, $7.152 billion; NASA, $4.192 billion (not counting certain operational costs for the space shuttle); DOE, $6.179 billion; NSF, $1.885 billion; Agriculture, $1.064 billion; and the National Institute of Standards & Technology (NIST, formerly NBS), $159 million.

In addition, it is estimated that Interior got about $396 million in R&D funds; Environmental Protection Agency, $335 million; Transportation, $317 million; and the National Oceanic & Atmospheric Administration, $176 million.

Gramm-Rudman will force Congress to reduce the budget deficit to $108 billion, even though OMB projects a $146-billion shortfall. If further cuts are required, they could come out of unprotected R&D appropriations.

Cutbacks in defense R&D are likely to ripple through the technology-based sectors of the economy. Congressional leaders on both sides of the aisle held fairly closely to the 3.0% increase agreed to at the December 1987 budget summit brought on by Gramm-Rudman-Hollings budget limits. Even the Strategic Defense Initiative got $800 million less than President Reagan requested.

"The research accounts in the defense budget took a real beating," says Ed McGaffigan, an aide to Sen. Jeff Bingaman (D-NM), member of the Senate Armed Services Committee. "They're not talking about major force reductions overseas, so if you don't cut people, you have to cut R&D."

The defense portion of DOE also faces trying times in 1989. A draft report leaked last October to *The Wall Street Journal* calls for the closing of nuclear-weapons facilities at Fernald, OH, and Rocky Flats, CO, and the streamlining of operations at three other sites. The cost to clean up these locations could run as high as $100 billion, says McGaffigan.

### No big jumps

Appropriations for nondefense R&D spending tracked the budget requests, says John Crowley, vice president of the American Assn. of Universities in Washington. Funding levels generally were "flat," he says, adding that "certainly there were no dramatic jumps" across the board.

There were exceptions, however. Sematech, the semiconductor industry manufacturing consortium, remains untouchable because it combines competitiveness with defense. Congressional aide McGaffigan predicts that Sematech will get $500 million over a five-year period, "no matter what the President requests."

A new "competitiveness" program, NSF's Science and Technology Centers, got $25 million for FY89, enough to start perhaps 10 to 12 interdisciplinary centers. However, Congress refused to give NSF director Erich Bloch a five-year, $150-million commitment to the program.

Other popular projects managed to evade the budget ax. Congress has awarded NIH, one of its pet agencies, nearly $600,000 more than the amount requested by President Reagan for AIDS research—about a 30% increase.

### Boost for NASA

NASA also came up with about a 30% increase in its budget, some $900 million of it going toward the manned space station. However, $515 million of that appropriation will have to be approved by the new President in May—and, given other budgetary concerns, it's not at all certain full funding will survive.

At the "nonweapons" Federal labs, "things look about the same," says Alan Schriesheim, director of Argonne (IL) National Lab. "We didn't get as much as we wanted for superconductivity research (a total of about $10 to 12 million)," he says. But Argonne, Los Alamos, and Oak Ridge will get $2 million each this year to foster superconductivity research be-

However, it became evident that the process industries were beginning to weaken at the end of 1988. Growth in shipments for paper, petroleum, and stone, clay, and glass products hit their high points in the third quarter of 1988, and inventory levels rose. As the economy stumbles this year, processors of industrial materials will be cutting back on output.

Overall, output for the process industries will fall by just 0.1% in 1989. Growth in output of primary metals and stone, clay, and glass products will inch up slightly. Toward the end of the year growth for chemicals, paper, rubber, and plastics products will slide into the negative zone.

### Some silver linings

This sag will squeeze R&D budgets in these industries. On the bright side, however, the impending downturn in the process industries will check the price spiral in industrial materials and reduce delivery times. So look for stabilizing or somewhat lower prices and a ready supply of many of the industrial materials you need to buy for your lab.

Industrial production from the original equipment manufacturers (OEMs) advanced about 7% in 1988. Nonelectrical machinery (in which the government includes computers and office equipment), fabricated metals, and instruments made strong output gains last year. Strong export markets and healthy domestic investment fueled OEM production in '88.

But the picture will change this year. Export growth won't be as robust, and business investment in equipment will be weak in 1989. Growth in OEM production will slow to a crawl in most sectors. The slowdown will be short-lived however, as industrial machinery and electronics industries regain strength in 1990.

Most likely, industrial funds for R&D will increase this year, but the rate of growth will be a trickle compared to the hikes we saw earlier in the decade.

Because the electronics industry has a lot riding on commercializing new technology and reducing product development cycles, expect some measure of real growth in R&D budgets for component, computer, and instrument manufacturers as they devote a larger percentage of annual sales to the R&D function.

*—Madeline Franchi*
*Cahners Economics Dept.*

## Having a new President in the White House doesn't mean that science and technology issues will get priority.

tween the Federal labs and industry.

The $4.4-billion superconducting super collider got a lift with the choice of Texas, home of President-elect Bush and House speaker Jim Wright, as the site. But SSC funding is still vulnerable, now that legislators from the 49 other states won't be feeding at the trough.

"It's such a combination of politics and science," says Argonne's Schriesheim. "You've got a small group of high-energy physicists up against the rest of the nation's scientists, and a Democratic Congress against a Republican President."

Nor is Washington throwing money at NIST, even though the 1988 trade bill suggests that the agency become a "civilian DARPA"—the Defense Advanced Research Projects Agency.

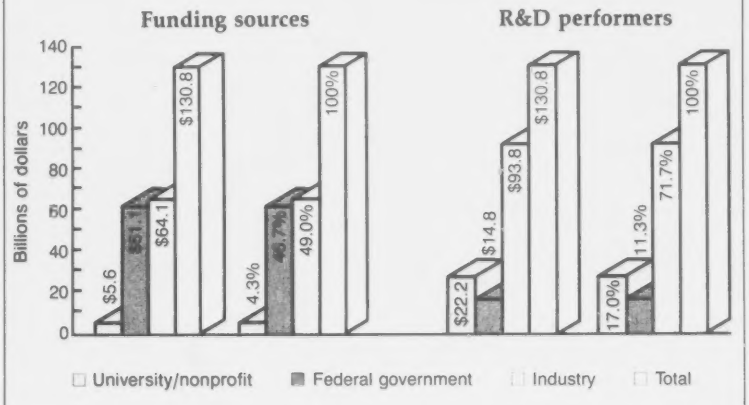
"Congress has given NIST a great deal of authorization and no money," says Lee W. Rivers, Washington representative for the Federal Laboratory Consortium (FLC).

Another policy change has to do with how Federal dollars are being dispensed to universities. "It used to be mostly outright grants for capital equipment," notes a spokesman for the Scientific Apparatus Makers Assn. in Washington. "Now, if you need a piece of equipment that's part of an approved project, you get it."

Looking ahead, 1990 looks as meager as '89. In the private sector, the general economic slowdown points to continued sluggishness in R&D spending growth for the early '90s.

One area that offers hope is technology transfer. "There does seem to be a sincere effort to try to market the know-how of the Federal labs," says Dow's Levitt. He says the pharmaceuticals industry is pushing NIH to release more of its research. "There's got to be something in there for industry," he says.

### Who will supply, spend 1989 R&D dollars?




*The Federal government and private industry will share most of the research costs in the U.S. in 1989, with industry carrying out the bulk of the work.*

### Breaking new ground

Another breakthrough came in the form of an invitation from Secretary of Energy John S. Herrington to 50 CEOs of R&D-based companies. The purpose of last December's scheduled meeting was to talk about the real problems of transferring technology from Federal labs to industry. "DOE is coming around on tech transfer," says Levitt.

At the Federal level, the election of a new President does mean that R&D interest groups will have "a new group of players to tell their story to," says Levitt.

But, he is quick to add, when you consider the more-pressing issues that the new Administration will have to tackle—the budget deficit, the trade imbalance, the savings-and-loan bailout, to name a few—"science and technology's concerns do not have that kind of immediacy."

So you've been warned: Don't count on any windfalls. **R&D**

### R&D tax credit gets another year of life

ONE BRIGHT SPOT for industrial research in 1989 is the one-year renewal of the 20% R&D tax credit, which provides a dollar-for-dollar reduction of taxes to companies for increases in their R&D budgets.

"That's good R&D, because it's occurring at the marketplace," says Joseph Saloom, chairman of the Council on Research & Technology, which lobbied Congress for the renewal.

The credit has been responsible for adding $4 to $5 billion in new R&D since 1981, says Brookings Institution senior fellow Martin N. Baily. Because the credit is based on a rolling three-year average of a company's R&D spending, however, the firm must spend more each year to get the benefit.

As a result, says Baily, the credit will probably produce only about $1 billion in "new" R&D funding by industry. Congress failed to approve a lesser tax break for companies that had earned the credit in the past but which could not put in additional new money in 1989.

"The pressure from [Ways & Means Committee Chairman Dan] Rostenkowski is so great to cut back on revenue losses, but I think that's a serious mistake," says economist Baily. "It's a nickel-and-dime part of the Federal budget, and most studies suggest that R&D is necessary to maintain our competitiveness." □

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R&D

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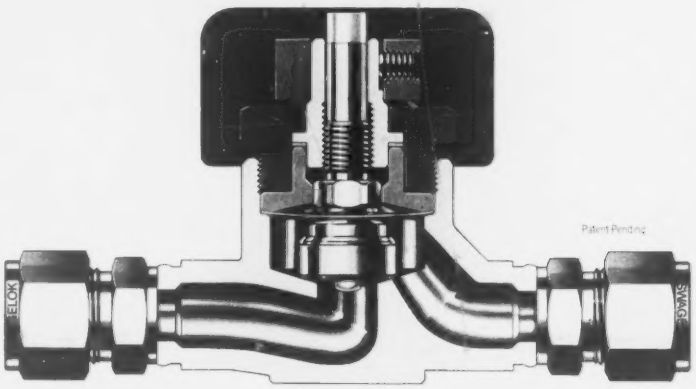


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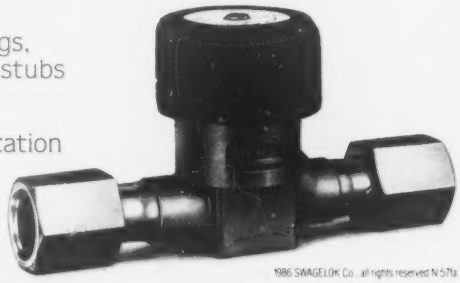

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The history of acronyms and symbols in language can be fascinating and confusing, writes Fred Jueneman in "Men of Letters," but the proclivity of today's society for acronyms is more confusing than fascinating.

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Too often in product development there is the feeling that time, money, and quality are related; however, it is important for managers to know the distinctions between the three, states Erwin Frand in "Quality Time."

## BUSINESS

### Instrument shipments to climb 3.1% in '89

SHIPMENTS OF SCIENTIFIC and engineering instruments will reach $50.6 billion in 1989, 3.1% over the $49.1-billion level set in 1988, says a Cahners Economics forecast.

But growth in the production of these instruments is expected to peak early this year, then settle down later in the year to a 5% annual level, says Cahners senior economist Madeline Franchi. That projection is down slightly from the 7% growth in instrument production in 1988, she adds.

In a separate report, Frost & Sullivan foresees a 50% increase in sales of analytical instruments from 1987 to 1992, to $3.5 billion.

The New York-based market research firm states that a "booming" biotechnology business will fuel the need for instruments in the next few years. Chromatographic products serving the needs of pharmaceutical, biotechnology, and life-science labs will be "big winners," says the report, with sales reaching $900 million by 1992. For more on the Frost & Sullivan report, **circle 893** on the Reader Service Card.

Franchi notes, however, that the analytical instrument market is "usually keyed to the amount of money available for R&D." Cahners Economics and *R&D* magazine project real-dollar R&D growth to be flat in 1989. □

### Buy a lottery ticket, help the cause of R&D

MINNESOTA HAS BECOME the first state to finance research through a lottery. By a 60-40 majority, voters in the land of 10,000 lakes last November approved creation of the nation's 30th state lottery. Half of the profits for the first five years will go into an R&D trust fund that could be worth as much as $300 million.

"We're the only state that will have permanent funding for research," says Terry Montgomery, acting president of the Greater Minnesota Corp. (GMC), a quasi-public corporation which will administer the endowment. The lottery should be operating by the end of the year, he says.

Montgomery estimates that the trust fund will generate $25 million a year in investment income, with another $25 million a year coming from corporate and other contributions. The endowment will "insulate the program from politics and from downturns in the economy," he says.

The money will be used to set up regional technology field offices, advanced manufacturing research centers, and several "applied research institutes" that will focus on promoting key technologies in the state, such as advanced materials, supercomputers, and biomedical products.

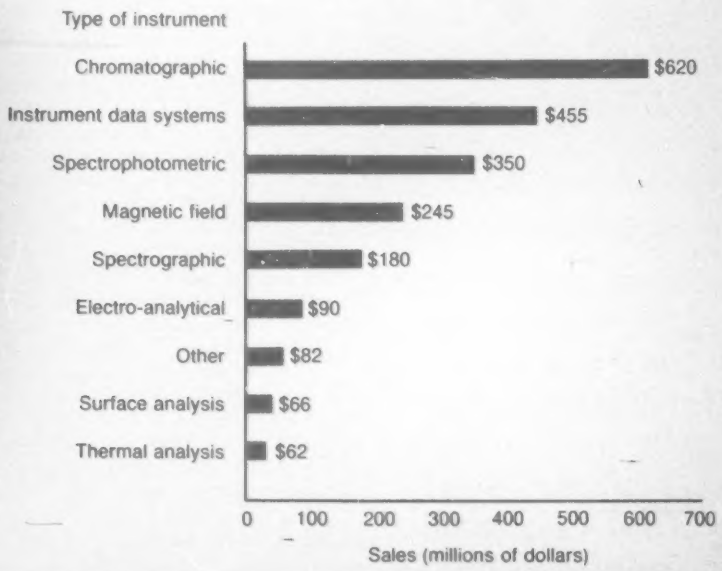
GMC has been operating since late 1987 with $30 million from the state legislature. Thus far, it has awarded $750,000 to the newly formed Natural Resources Research Institute in Duluth to find new uses for Minnesota wood products. Research into biodegradable plastics also is under way.

Montgomery says up to $3 million will be set aside for "technology challenge grants" to university researchers, with another $5 million going to capitalize a venture capital seed fund.

For information, contact GMC, 920 Second Ave. S., Minneapolis, MN 55402; 612/338-6666. □

*R&D Business continues*

***Chromatography products** will be "winners" in the analytical instruments sweepstakes, says the marketing firm of Frost & Sullivan. (Photo: Neslab Instruments Inc.)*



# R&D

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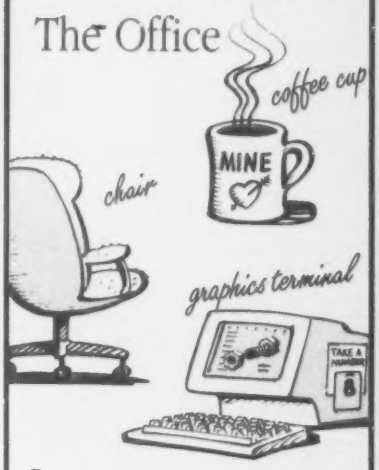
Three Things
You Shouldn't
Have To Share At
The Office

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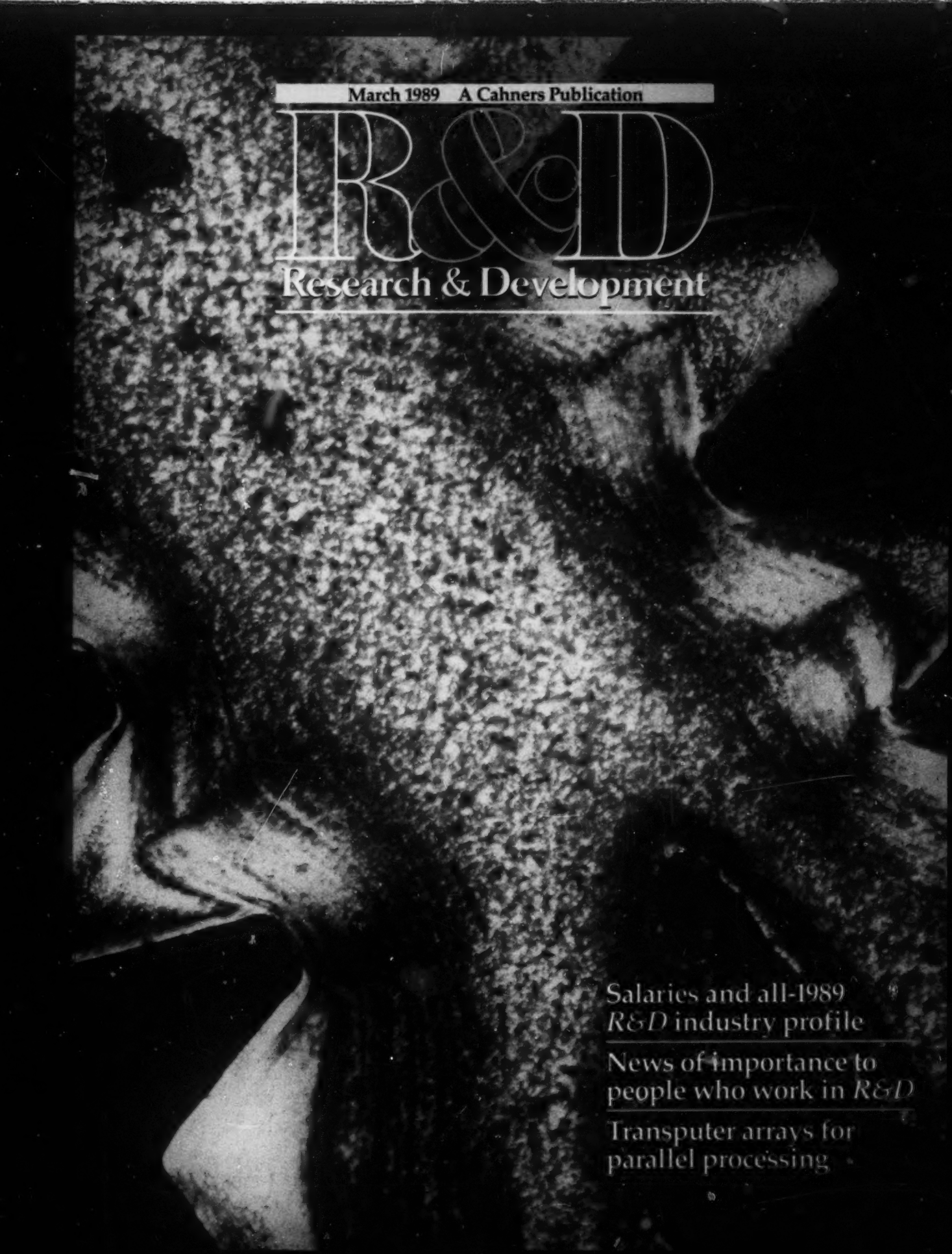
Circle 845 for product information

March 1989 A Cahners Publication

# R&D

## Research & Development



Salaries and all-1989 *R&D* industry profile

News of importance to people who work in *R&D*

Transputer arrays for parallel processing

# R&D

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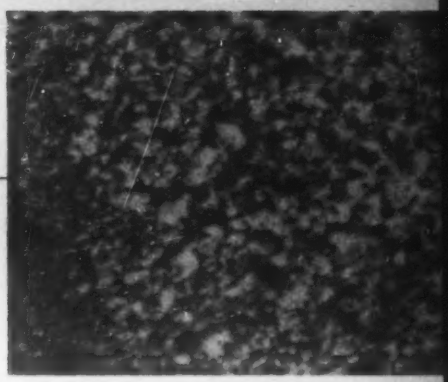


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*Robert R. Jones, Editor,* R&D *magazine*
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***Researchers at** Carl Zeiss Inc. produced this micrograph of a screw made of "Delrin" (an acetal homopolymer) using a Plan-Neofluar objective with a Lambda plate and using transmitted light with a crossed polarizer and analyzer.*

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Through the ages, the travels of humankind have led to several changes in the calendar, Jueneman says in "Essence of time." Now, as we consider long-distance space travel, another calendar revision may be necessary.

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# HTS, AIDS research should get top priority for funds, scientists say

AN EXCLUSIVE *R&D* magazine survey shows that scientists and R&D managers favor giving top priority for Federal research dollars to high-temperature superconductivity (HTS) and AIDS.

The survey of 1,000 scientists was designed to provide guidance to Congress and the White House on science and technology policy. It revealed that:

- A wide majority (73%) of respondents want overall Federal funding for R&D increased—by a median amount of 10%.
- A clear majority (56%) would slash defense-related R&D. Taking all responses into account, scientists favor trimming defense R&D by a median of 5%.

"Too much defense-related expenditure saps R&D talent away from private-sector needs," said one materials scientist.

- An overwhelming 86% favor increasing civilian-related research—by a median of 10%, taking all responses into account.
- Scientists believe that any increase in Federal R&D should be paid for by cutting defense spending (66%), increasing Federal taxes on cigarets and liquor (63%), and boosting R&D tax credits to the private sector (60%). Totals exceed 100% because respondents were asked to list three choices. (See chart on following page.)

### Paying for big science

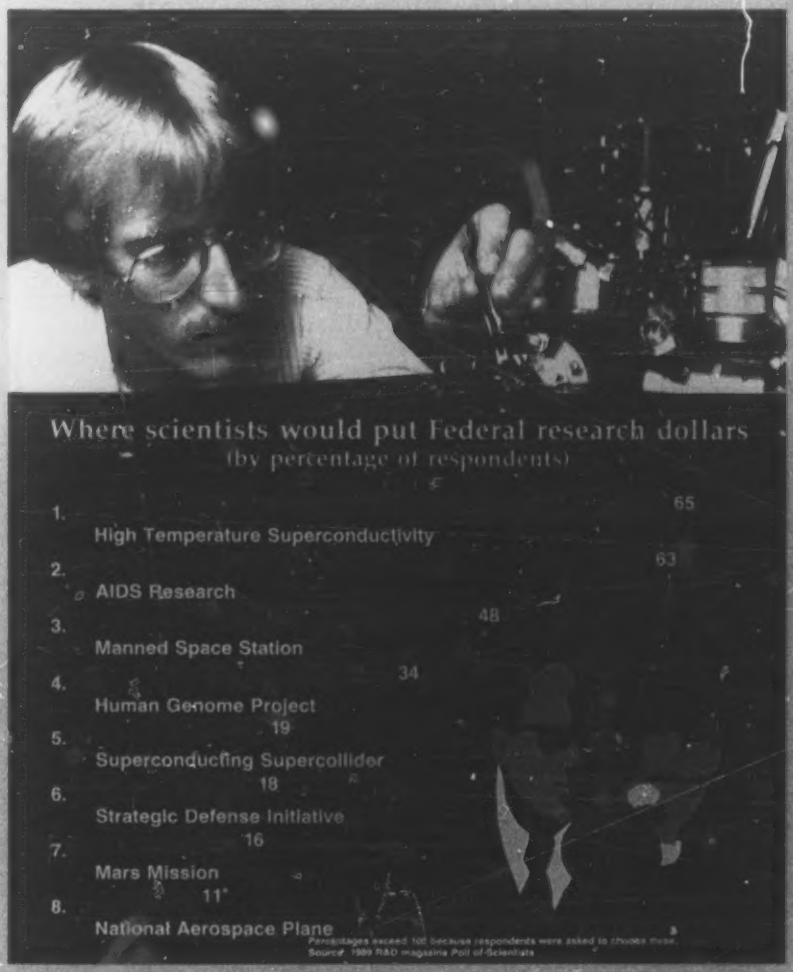
Asked to list the three most important science programs in order of priority, scientists singled out research on high-$T_c$ superconductivity (65%) and AIDS (63%) for Federal funding priority. The manned space station was listed by 43% of respondents (see chart).

One respondent criticized the "megaprojects" approach to research in favor of individual, peer-reviewed projects. "The trend toward 'big science' already is decreasing the quality and quantity of science" in America, said researcher Doug Frank, a university-based analytical chemist in Ohio.

In line with their general lack of support for defense-related R&D—only 19% favored increasing defense R&D while 25% said it should remain the same—respondents gave the Strategic Defense Initiative only moderate support (18%). As one analytical chemist employed by the government put it: "With SDI, funds and person-hours are diverted from more-practical projects."

One item that was not on the list—cleaning up the environment, particularly of toxic wastes—drew considerable response anyway. "I'm *very* disappointed that environment was not included" among the choices, said Michelle Herrera, a drug-company chemist in Massachusetts. "Shame on you!"

The survey was mailed in January to a randomly selected sample of 1,000 scientists who attended the 1988 Pittsburgh Conference. More than 260 valid responses were received, making the results projectable at the 95% confidence level, with a


Where scientists would put Federal research dollars
(by percentage of respondents)
1. High Temperature Superconductivity 65
2. AIDS Research 63
3. Manned Space Station 48
4. Human Genome Project 34
5. Superconducting Supercollider 19
6. Strategic Defense Initiative 18
7. Mars Mission 16
8. National Aerospace Plane 11
Percentages exceed 100 because respondents were asked to choose three.
Source: 1989 R&D magazine Poll of Scientists

***High-temperature superconductivity and AIDS research topped the list of science "megaprojects" worthy of high priority for Federal funding, an exclusive R&D magazine survey of Pittsburgh Conference attendees shows. (Photo: Kevex Instruments)***

statistical margin of error of ±6%.

Respondents were asked to give the single most important R&D-related issue they face. An electrical engineer whose company makes DNA sequencers said, "Getting corporations to spend money on R&D rather than on M&A" (mergers and acquisitions). Another respondent, Dane Karr, senior scientist with a Pennsylvania plastics company, exclaimed, "Corporate takeovers! What a threat!"

### Short-term priorities

The lack of long-term corporate thinking bothered a number of those polled. "The fact that short-term performance takes priority over long-range plans and projects makes a long-term strategic approach to a technical market difficult or impossible," said Dr. James Shoolery, an NMR applications chemist with Varian Instrument Div., Palo Alto, CA, and *R&D*'s 1983 Scientist of the Year.

Jay Russell, a chemist with Chembond Corp., Springfield, OR, agreed that "the need for immediate results from research projects" is a major problem. One analytical chemist said that, at his firm, "research is something a few people dabble in to keep Wall Street happy but is not taken seriously by the company." An organic chemist said his company "has been run by 'bottom liners' with no foresight" who are "only concerned with the next quarter."

Another scientist bemoaned the "lack of long vision and commitment to extended research," while a chemicals researcher decried the "dependence of the R&D budget on sales." Yet another, in the energy-products area, criticized "restrictions on the kind of 'research' that can be pursued—benefits must be immediately evident."

Others complained that cutbacks in R&D budgets often prevented them from buying the latest equipment or hiring enough staff. An aerospace industry researcher noted that "competition has reduced corporate R&D spending in order to increase manufacturing improvement spending."

David Burge, an analytical instruments consultant in California, said his problem was "finding a way to use a variety of technologies in a small company which cannot afford to support all of the needed talent."

### Tied up in red tape

Many of those in industry blame Big Government for some of their problems. A researcher at a New Jersey drug company said he sees "excessive legal requirements for documentation" of data by regulatory authorities.

The director of analytical research for a New Jersey drugmaker was distressed over the "incompetence" of personnel at Federal agencies such as the Food & Drug Administration. "Sometimes they don't even understand the terminology of the drugs they're supposed to be regulating," he said.

Overregulation may be hurting U.S. industrial competitiveness, said one chemist who makes resins for coatings and adhesives. The solution, he said, will require "finding a way to obtain cooperation between related U.S. industries without getting into trouble with the government," presumably over antitrust laws. "This would improve our ability to compete internationally."

But not all red tape comes from Washington, as Ciba-Geigy's Michael K. Pastorcich noted in describing the general problem he sees of "meeting competition (foreign and domestic) within the bureaucratic structure of a large corporation."

### People problems

Many respondents echoed the concern of Dr. Terry Ramus, project manager for a California chemicals firm, who sees "insufficient talent available." Said Ramus, "More emphasis has to be placed on developing future researchers."

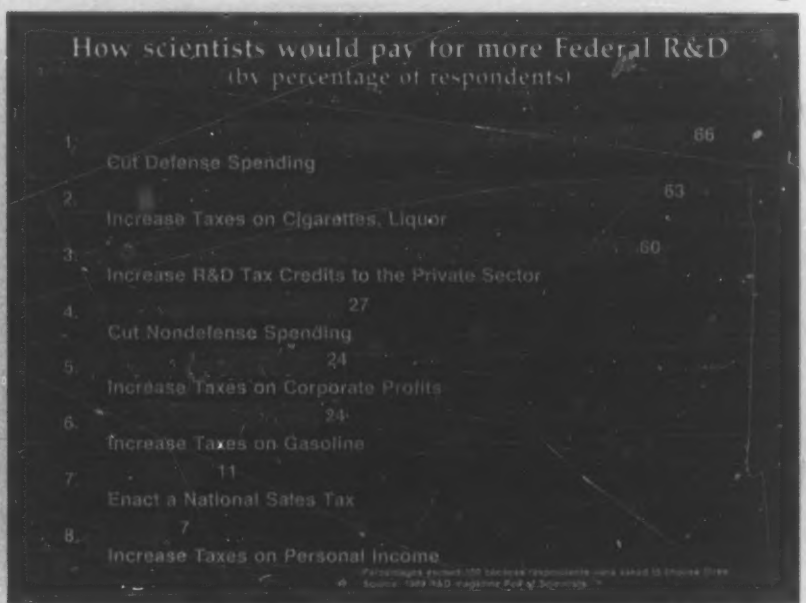
Materials scientist Rick Beaver, project manager for a Pittsburgh-area R&D firm, also complained about a "lack of qualified scientists," as did government R&D project manager Paul Mogan of the "lack of qualified civil-service manpower." Dr. Jan St. Pyrek, who runs the mass spectroscopy lab at Rice Univ. in Houston, worries about the "lack of students devoted to science."

Ted Westlake, a chemist with a Louisiana petrochemical company, added that "universities are teaching students to be teachers, not industrial researchers."

A few respondents are worried about workplace conditions. John Robbins, group leader for R&D analytical services at Hershey Foods Corp., Hershey, PA, said he is concerned about the "isolation of R&D personnel" and the "prejudice and lack of understanding by nontechnical associates and peers" of their work. "I want to see more technical people in the ranks of executives," he said.

An engineer whose company makes hemodialysis devices is annoyed by "the impossibility" of R&D people getting into management, which he said is "occupied by sales and marketing-educated 'experts.'"

Martin T. Scott, an environmental chemist in Delaware, may have put his finger on the biggest problem of all, the "lack of knowledge by the public and politicians of what is involved in research."—*Robert Cassidy*


How scientists would pay for more Federal R&D
(by percentage of respondents)
1. Cut Defense Spending 66
2. Increase Taxes on Cigarettes, Liquor 63
3. Increase R&D Tax Credits to the Private Sector 60
4. Cut Nondefense Spending 27
5. Increase Taxes on Corporate Profits 24
6. Increase Taxes on Gasoline 24
7. Enact a National Sales Tax 11
8. Increase Taxes on Personal Income 7

***Survey respondents clearly favor cutting defense spending, boosting "sin" taxes, and providing more R&D tax credits as the way to finance an increase in Federal R&D.***

# Salaries Are Up Substantially For People Who Work in R&D

*R&D* magazine's annual profile of the industry shows that median income increased more than 9% in the past year.

*By* ***Robert R. Jones****, Editor, R&D magazine*

OVER RECENT YEARS, the salary picture for workers in research, development, and quality assurance has varied regularly from bright to gloomy and back. This year it looks brighter than it has in a long time.

Median income for all workers in this industry is up a significant 9.25% this year, which—after allowing for inflation—means 4% in real gain!

As a result, gross salary income for workers in this industry now exceeds $28.45 billion/yr in the U.S. alone.

These and other conclusions reported in this article are based on the responses of more than 1,700 readers of *R&D* magazine.

### Salary spread widens

As was mentioned in last year's profile of the industry, the once-classical Gaussian distribution of salaries in the R&D industry has become distorted.

Despite the increasing distortions, for the four prior years the peak (representing the largest number of workers within a salary range) had stayed in the same location—the $40,000 through $44,999 range.

This year the most-populous salary range and the peak of the curve have moved up two positions to the $50,000 through $54,999 range.

The curve has not moved in its entirety. There still are workers in R&D who are earning less than $15,000/yr and quite a few in the $15,000 through $19,999 and $20,000 through $24,999 ranges.

Thus, the curve has broadened to span an income range of $70,000/yr. It has become more shallow, with this result:

In 1986, 60.8% of workers in research, development, and quality assurance who responded to our survey reported salaries in the ranges from $35,000 through $59,999.

Last year that figure had dropped to 58.7, a decline of 3.5%. This year 57.3% of R&D workers are in that span after a further drop of 5.76%.

### A lower peak

The salaries of many workers who were in the $35,000 through $59,999 range have moved up. Inflation has been a small factor, but the normal rewards in this industry for age and experience were larger factors. At the same time, these individuals have not been fully replaced in the lower ranges and, thus, the peak is lower.

Specifically, the portion of respondents in the salary ranges above $59,999/yr is more than 2.5 times as large as it was two years ago. It has increased from 8.7% in 1986 to 14.4% in 1987 and to 22.1% last year.

After adjusting last year's salary increases for inflation, 44.2% of workers in R&D had an increase in income. This is the lowest such figure since 1984.

An accompanying table (facing page) shows the distribution and size ranges of salary increases for workers in R&D for the years from 1984.

With a larger portion of R&D workers in the higher salary ranges this year, the median salaries for workers in all disciplines have moved upward. In fact, this year's median salary, with the 9.25% rise from last year mentioned earlier, reverses a downward trend. Previous median salary gains have been 1985 6.3%, 1986 3.2%, 1987 4.3%, and 1988 0.4%.

One result of the higher salary ranges is that no discipline's workers suffered a loss in median income; the first time in several years that there have been no losses.

Data from this year's survey place the median salary for ceramists four notches higher than it was last year, and in line with those of preceding years, suggesting that last year's ranking could have reflected an error.

It may seem to industrial engineers that there is something to the old line about the rich getting richer.

Aeronautical engineers, who have ranked first both this year and last in median annual salary, made a gain of 8.7% this year to $57,500 while the industrial engineers, last in the rankings both years, gained 1.7% to $38,125/yr.

### A $20,000 span

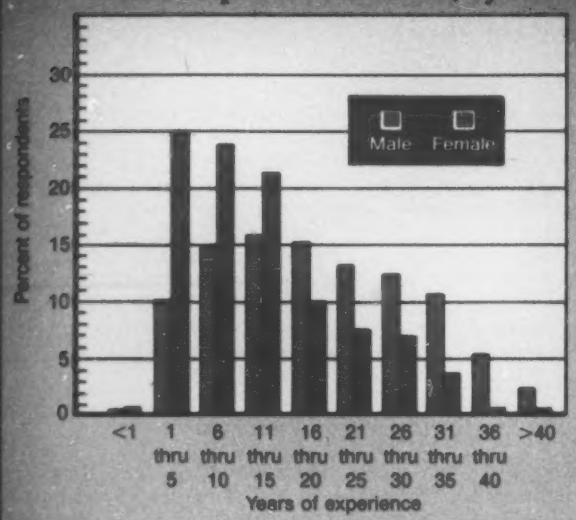
Thus the span from low to high median increased from $15,417 last year to $19,375 this year. A result of this is that the typical aeronautical engineer's salary now is more than 150% as large as the typical industrial engineer's.

For workers in research, development, and quality assurance, there is a strong correlation between salary and years of experience. This is demonstrated in the chart of median years of experience in each salary range.

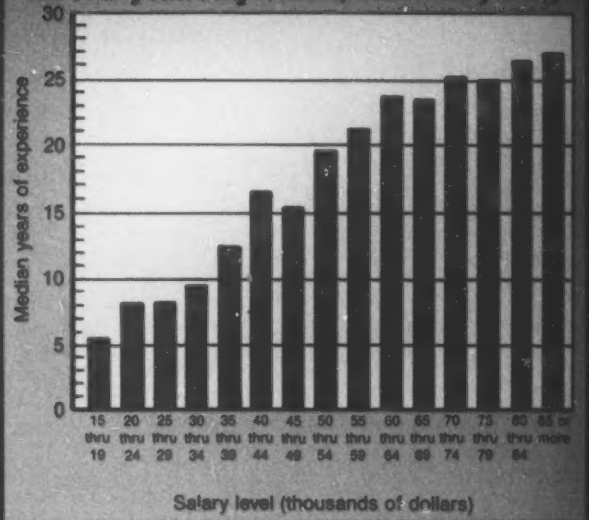
In this chart there are only three small exceptions to total correlation.

The respondents who reported a

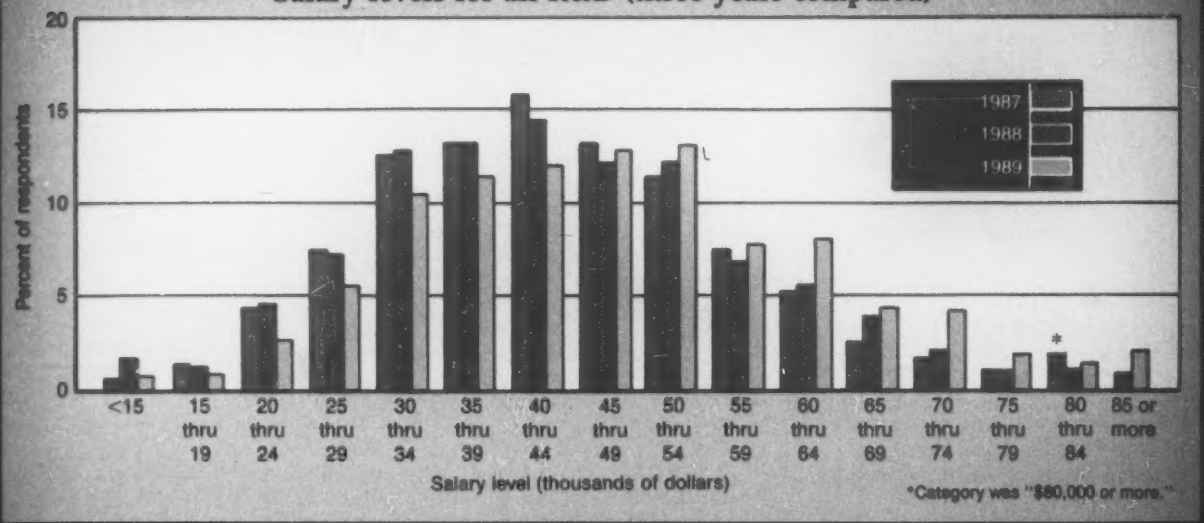
## Years of experience—all R&D, by sex




## Median years' experience, each salary range




## Salary levels for all R&D (three years compared)




*Category was "$80,000 or more."

## Increases in rate of pay*

| Amount of increase | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 |
|---|---|---|---|---|---|---|
| | Percent of respondents | | | | | |
| None | 9.3 | 14.5 | 16.5 | 11.3 | 9.3 | 16.3 |
| Less than 2% | 5.3 | 6.3 | 4.3 | 3.6 | 2.9 | 2.1 |
| 2 through 5% | 54.8 | 49.8 | 39.2 | 37.1 | 36.6 | 26.9 |
| 6 through 9% | 22.2 | 21.7 | 30.8 | 36.3 | 37.6 | 38.9 |
| 10 through 13% | 5.6 | 4.7 | 6.0 | 8.3 | 10.1 | 11.5 |
| 14% or more | 2.7 | 3.0 | 3.2 | 3.3 | 3.6 | 4.4 |
| Ahead of inflation | 44.2 | 46.0 | 79.2 | 60.1 | 63.3 | 54.8 |

*Granted in preceding year for year shown.

## Discipline rankings by median salaries

| Rank 1989 | Rank 1988 | Discipline | Median salary 1989 | Median salary 1988 | Percent increase |
|---|---|---|---|---|---|
| 1 | 1 | Aero. Engr. | $57,500 | $52,917 | 8.7 |
| 2 | 2 | Metallurgist | 52,205 | 49,375 | 5.7 |
| 3 | 4 | Physicist | 51,087 | 47,955 | 6.5 |
| 4 | 3 | Geologist | 50,500 | 48,750 | 3.6 |
| 4 | 8 | Ceramist | 50,500 | 43,750 | 15.4 |
| 6 | 5 | Elec. Engr. | 50,185 | 45,476 | 10.3 |
| 7 | 6 | Chem. Engr. | 49,100 | 45,109 | 8.8 |
| 8 | 7 | Mech. Engr. | 48,900 | 44,828 | 9.1 |
| 9 | 9 | Chemist | 45,243 | 42,113 | 7.4 |
| 10 | 11 | Biologist | 43,846 | 40,625 | 7.9 |
| 11 | 10 | Mathematician | 42,500 | 41,250 | 3.0 |
| 12 | 12 | Indust. Engr. | 38,125 | 37,500 | 1.7 |

## When salaries are keyed to experience, women often come up short.

salary of $85,000/yr or more also show the highest median years of experience, at 26.9. Close behind, workers reporting salaries of $80,000 through $84,999/yr have the second-highest experience median at 26.3.

Here is where sex differences begin to appear in salaries. For numerous good reasons, it is difficult for a woman to have as many years of experience in research and development or quality assurance as a man may have.

The situation is displayed in the years of experience by sex chart. It shows that nearly half of the women respondents have less than 11 years' experience. Only a fourth of the men have less than 11 years' experience.

Thus 50% of the women and 75% of the men are in the more-experience-means-more-pay category.

It can hardly be surprising, then, that 48.1% of the female respondents to this survey are in salary brackets below $35,000/yr, while only 17.6% of the men are in that range.

### At the upper end

At the upper salary end, generally populated by individuals with many years of experience, 8.2% of the female respondents are getting

## The educational profile of the technical professional in R&D environments

*By George A. McGinn*

HELPING to maintain the technical vitality of the professional employe is one of the primary considerations of an industrial education support program.

However, comparisons of current educational profiles of professionals in high technology environments are not commonly available.

One of the few complete published profiles available is contained in *Organizing for Innovation* (1), which gives a complete view of the Bell Telephone Laboratory in the mid-1960s.

The U.S. Dept. of Labor Bureau of Labor Statistics (BLS) publishes material related to the training needed to enter various occupations. As an example, data from BLS Bulletin 2251 (2) show that 63% of the work force of electrical/electronic engineers needs four or more years of college to qualify for their jobs.

For many years, *Research & Development* magazine has published an annual survey containing educational breakouts in addition to salary data for a variety of engineering and scientific occupations (3).

From those surveys, the upper chart at right shows the educational profile averaged over the years 1983 through 1986 for three engineering occupations. As one might expect, the profile is shifted significantiy toward a more-educated work force within the high technology segments surveyed by *R&D*.

For example, in the BLS study, only 58% of the mechanical engineers have four or more years of college as compared to 84% in *R&D*'s study.

Using data from the IBM Endicott site (4), the educational level was collected for technical professionals in two 10-yr service ranges 25 yr apart. In addition, a projection for 25 yr from now is presented at lower left.

The Endicott facility, IBM's oldest site, is typical of high technology and manufacturing facilities in this country over the past 25 yr.

The most striking feature is the shift from engineers not holding degrees to those with BS degrees. MS and PhD holders also have increased significantly over the same period.

The projection shows the nondegree component, which shrank to a seventh of its size over the past 25 yr, becoming almost negligible.

The bachelor degree component, which grew by 300% in the first 25 yr, will decline as a percentage in the second. The MS component will continue to grow and become the most-common one, although the percentage of growth will be less in the second 25 yr.

Finally, the PhD component will continue to grow at the rate that it has during the past 25 yr, reaching 20% of the total professional staff.

### Technical vitality

Three major parameters are related to the technical education needed to maintain vitality: educational level, total years of service, and specific occupation of the individual.

For an occupational group, the education and service parameters can be displayed by means of the 3-D bar chart shown. This format displays the total target population on a single chart.

Each bar represents the number of individuals with a specific education level and a given length of service. The left-hand column shows the education levels for all service years.

The top row shows the total of individuals in each service interval. Finally, the extreme upper-left-hand bar shows total population.

This allows easy identification of specific groups that might need emphasis. A common influence on the educational breakout is the historical hiring pattern within an industry or company.

From the previous figure, we see that the ratio of education levels for new hires has changed significantly over the past 25 yr. Thus the specific time frame of a hiring variation can influence the total education mix in a given group.

In the third figure, the number of employes with 10 to 19 yr of service is low. This corresponds to a time when bachelor degrees dominated the hiring pattern.

Thus, the total population could be expected to have a lower percentage of bachelor degree holders than if a constant hiring pattern had been maintained.

For general planning purposes, assumptions can be made about the average total technical vitality education. For example, we could assume that those with less than 10 years' total service will require a minimum of 20 hr/yr while those with more than 10 yr will need an average of 40 hr.

Given these assumptions and the population shown in the third figure, a total of 13,960 hr of education could be expected. The breakout by education level also can influence the type and potential source of the vitality education needed.

As an example, for the data in the third figure, 20% of the total education is for engineers holding MS

$60,000/yr or more while 23.7% of the males fit into that range.

In the sidebar below, George A. McGinn looks at the educational profiles of technical professionals.

In the second part of this industry survey we will look at how the level of education has affected the salaries of the respondents. We also will see how well an investment in additional years of training can pay dividends in increased income over the years of an individual's career.

Charts will show comparisons for raise, salary range, years with present employer, level of education, years of experience, and age of respondents for 12 disciplines.

Finally, details on median salaries by workplace will suggest benefits or lack thereof for workers in government, university, or industry. **R&D**

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or PhD degrees. The level of material needed for their vitality would differ significantly from the level needed for those engineers holding bachelor degrees (39%).

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1. Morton, J.A., *Organizing for Innovation*, McGraw-Hill, 1971.
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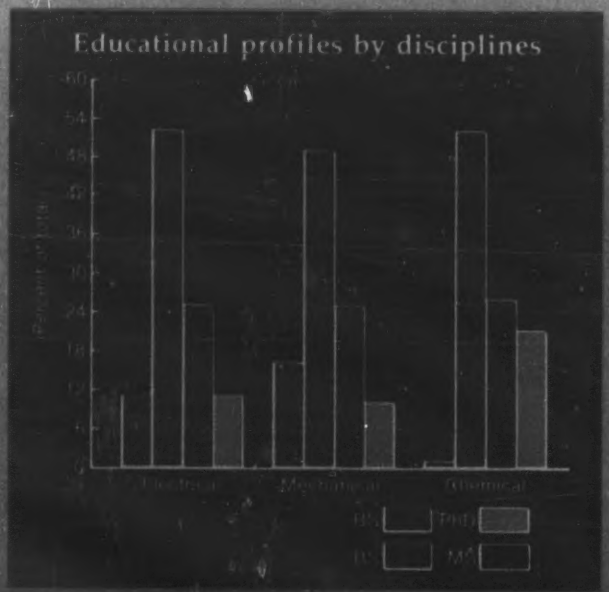
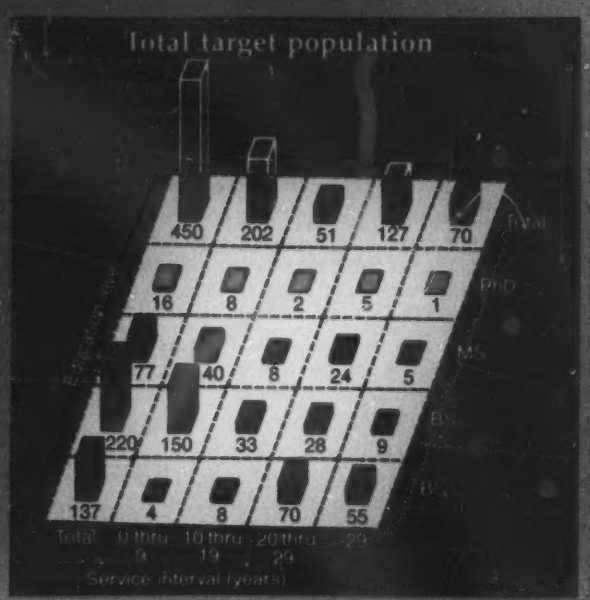
**George A. McGinn** is an advisory education requirements planner at IBM, Endicott, NY. He has held education and programming assignments at IBM, and spent many years at SUNY—Maritime College and holds degrees from Manhattan College and Fordham Univ., all in The Bronx, NY.



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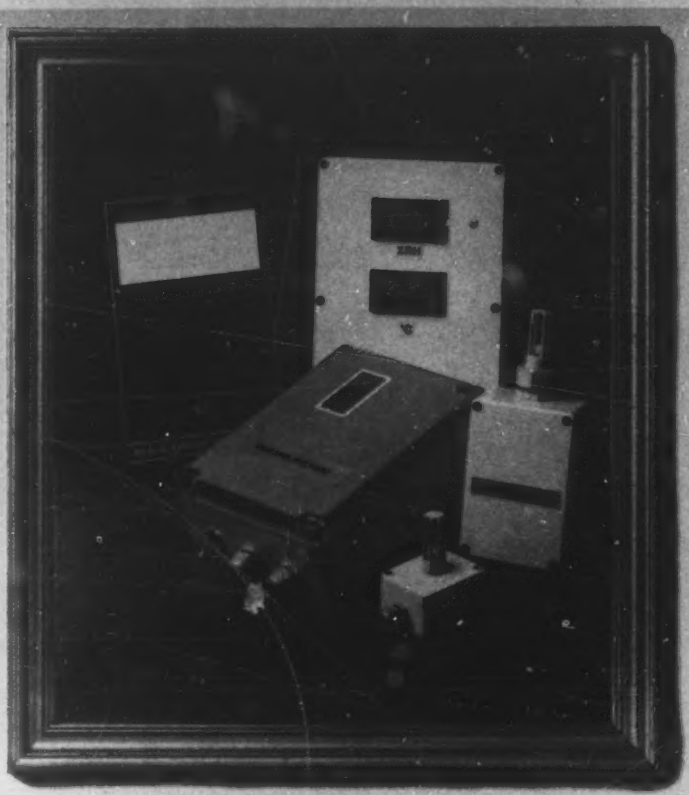

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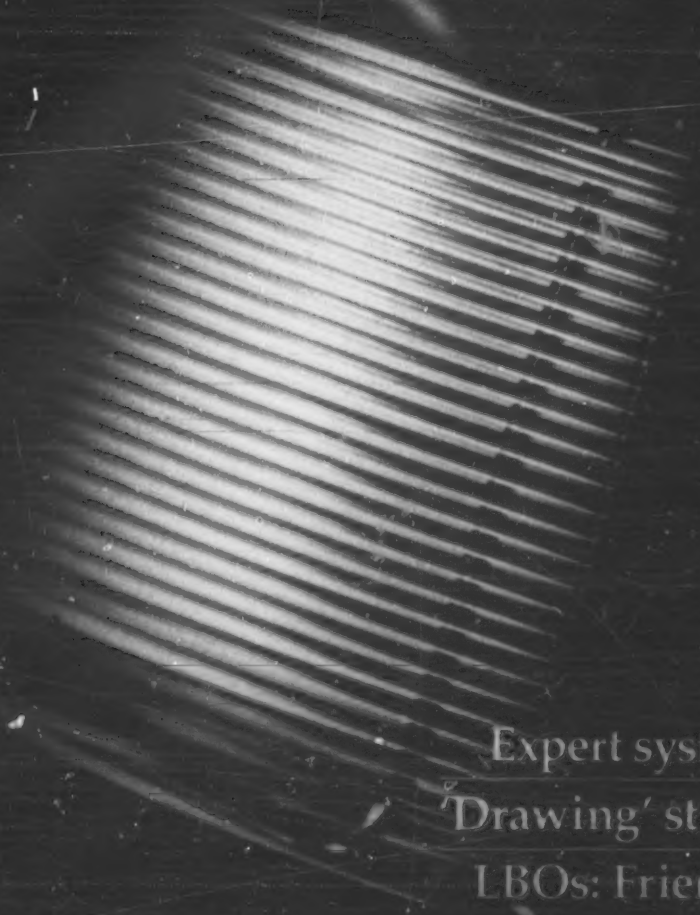

Expert systems come to the lab

'Drawing' stronger synthetic fibers

LBOs: Friend or foe of research?

# R&D

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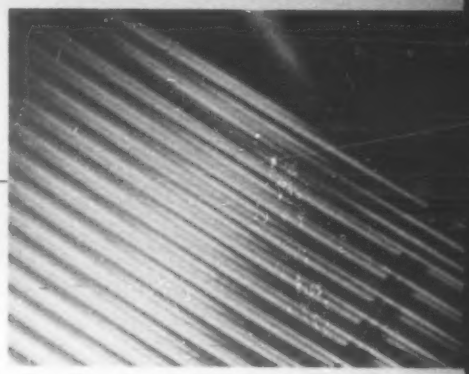


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BUSINESS

## LBOs: Friend or foe of industrial research?

NEW INFORMATION points the finger at leveraged buyouts (LBOs) for decreasing the amount of R&D spending in acquired companies. In its annual Survey of Industrial Research and Development, the National Science Foundation cites a 12.8% reduction in R&D spending between 1986 and 1987 for companies involved in LBOs and a 5.3% cut in overall takeovers.

Other companies in the survey that were not involved in restructurings averaged a 5.4% increase in R&D spending.

There has been little to substantiate the effect of buyouts on R&D, but critics believe that the massive amount of debt financing created by a company during such a buyout severely limits all major investment, including that for R&D.

In an extensive study of 300 takeovers (through 1985) for the NSF and the National Bureau of Economic Research, UC-Berkeley economics professor Bronwyn Hall found meager evidence that acquisitions affected R&D activity. While the majority of the companies she studied were not LBOs (most LBOs are in private, nontraded issues, and specific data are unavailable), she contends that "the private [LBOs have] nontechnical R&D, and vice versa."

Hall, who admits that her data are several years old, does not dispute the NSF study. There was a substantial change in the leverage (debt-equity) ratio for takeover companies in the final years of her study, prompting her to examine leverage ratios in more detail in a follow-up study, which she expects to complete in early 1990.

The Brookings Institution's Margaret Blair agrees with the NSF report, stating that while the number of restructured companies in the NSF study may be small, as a class the companies account for 90% of total

## Do leveraged buyouts hurt the flow of research?

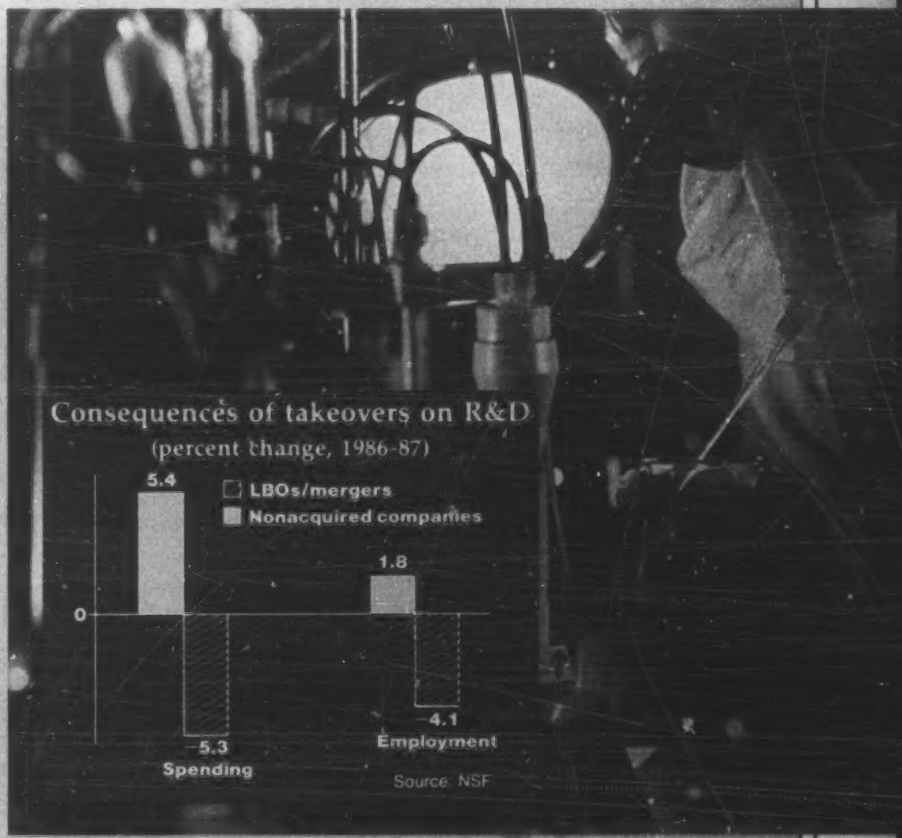
AN OFTEN overlooked aspect that all takeovers have on R&D activities is the loss of research continuity. Even if R&D funding and manpower levels remain stable, if research facilities are not consolidated, and if most administrative and staff personnel stay in place—all of which rarely happens in a takeover—new ownership almost always has its own ideas on the directions that R&D should take.

Richard Mateles, formerly vice-president of R&D for Stauffer Chemical and now a vice-president at IITRI, has experienced this situation on several occasions.

When Stauffer went through five ownership changes in three years, Mateles found that the first new owner followed a normal transition but made a "major change in direction to apply more R&D to consumer products. Personnel were reassigned, and it took more than a year to obtain initial results."

Successive owners made more changes, which caused R&D personnel to again reorient their priorities. During each episode it took several months to return to normal productivity levels.

Stauffer's initial three R&D groups each were sold to separate companies. Two units remained well directed despite the changes, while one lost key personnel. □




*Takeovers result in reduced spending in research and cuts in R&D staff, a new National Science Foundation study of 200 companies reports.*

industrial R&D expenditures. "Economic data two to five years from now will reveal the current rate of investment [for LBOs] to be cut way back," she says.

Blair bases current LBO activity on the high real cost of investment that has been in effect for the past decade. "In a microeconomic, or short-term, sense, LBOs may be the proper business investment response for a company with available cash, but in a macroeconomic sense it eliminates the R&D and capital investment needed for long-term high growth." □

## NSF compares U.S. and Japan on R&D spending

A NEW National Science Foundation study shows that the U.S. and Japan spend comparable amounts on research and development. But in Japan, a greater share of R&D funding comes from industry.

"In Japan, there's more self-funded industrial R&D," says Maria Papadakis, the NSF science resources analyst who wrote the report. In the U.S., she explains, much of the research that industry performs is funded by the government, particularly for defense work.

According to "The Science and Technology Resources of Japan: A Comparison With the United States" (NSF Report 88-318), Japanese industrial R&D expenditures increased at an average annual rate of 11% from 1965 to 1985, the last year for which figures are available. Company-funded R&D in the U.S. increased at only a 5% rate during that period.

In some sectors the spread was even greater. For example, Japan's ceramics industry outspent its American counterpart by 62% for research in 1985. In fabricated metals, Japanese companies spent 17% more on R&D than did those in the U.S. In iron and steel, the difference was 192%.

"There is a perception that the Japanese are outstanding in materials, and these data are further evidence that they're putting a lot of effort into that area," says Papadakis.

One factor that could slow Japan's R&D capability is a likely drop in scientists and engineers due to demographic changes. The U.S. has been facing a similar shortfall, but made up for it by "importing" researchers from abroad, something the Japanese may be reluctant to do. □

### The top 20 companies: A Japanese view

| | | |
|---|---|---|
| 1. | IBM | U.S. |
| 2. | Glaxo | UK |
| 3. | Nippon Tel. | Japan |
| 4. | DEC | U.S. |
| 5. | Brit. Tel. | UK |
| 6. | Ford | U.S. |
| 7. | Exxon | U.S. |
| 8. | Bell South | U.S. |
| 9. | Royal Dutch | Holland, UK |
| 10. | General Motors | U.S. |
| 11. | Toyota | Japan |
| 12. | Philip Morris | U.S. |
| 13. | Tokyo Elec. Pwr. | Japan |
| 14. | Brit. Pet. | UK |
| 15. | DuPont | U.S. |
| 16. | NYNEX | U.S. |
| 17. | Hanson | UK |
| 18. | Bell Atlantic | U.S. |
| 19. | Cray Research | U.S. |
| 20. | Ameritech | U.S. |

## Japanese rank IBM as the world's top company

AN ANNUAL SURVEY conducted by Nihon Keizai Shimbun Inc. *(Japan Economic Journal)* ranks IBM as the best company in the world for the third consecutive year. The top 100 companies (with sales of more than $90 million) included 60 from the U.S. (down 10 from 1987), 15 from the UK (up 4), and 11 from Japan (up 4).

Rankings for the survey are based on 16 factors including asset base, profitability, stability, and financial performance. Japan's Nippon Telegraph & Telephone scored high on its huge assets, although its financial performance was rated lower than that of IBM and Glaxo.

High technology companies continued to be highly ranked, but several companies in basic industries also claimed that status this year, indicating economic expansion to more industrial sectors. □

## Composites industry to expand research

MORE COMPOSITES and plastics companies plan to expand their R&D budgets in 1989 than in 1988 (64% *vs* 57%). More than half of those surveyed in Owens-Corning's annual survey of the industry, "Trends '89," believe that their companies will increase R&D spending an average of 20%. More than half also spent more on R&D than was budgeted for 1988.

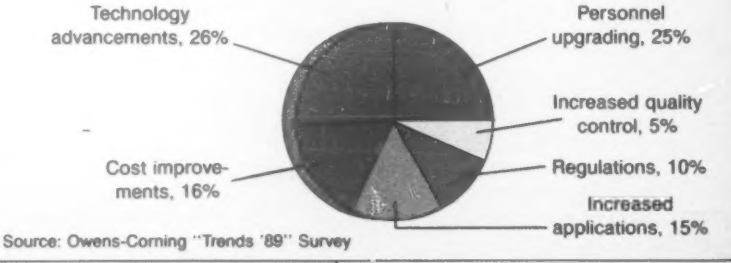
The development of new materials continues to be the area where more than half of the R&D money will be spent. But materials development dropped from being the most important issue for company executives due to a dramatic increase in the importance of health and safety issues.

"One reason for this increase," cites Robert DeGange, Owens-Corning's vice-president for industrial materials, "may be the ruling by OSHA to limit the permissible exposure levels of chemicals in the manufacture of composites." Another factor could be the EPA's requirement for full disclosure of the use or release of toxic chemicals.

Partnerships between composites companies have proliferated, with 90% of the survey respondents stating that they had developed cooperative research arrangements. More than a third of these partnerships are with foreign firms, even though 85% of composite sales are domestic.

The survey also revealed that for those already involved in development partnerships, joint R&D increased from 76 to 86% in 1988. For those entering into new partnerships, the joint R&D rate increased from 41 to 59%. □

### What factors will affect industry growth?




Source: Owens-Corning "Trends '89" Survey

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R&D

CIRCULATION

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May 1989 A Cahners Publication

# R&D

Research & Development

Special Report:
The FSX controversy

Wafer cleaning
without surface damage

A most unusual
Lab of the Year

R&D

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***New equipment and techniques** for semiconductor research include high-vacuum process chambers (cover), photo-induced surface cleaning (page 74), and handling of toxic waste gases (page 107). Photo courtesy of Nor-Cal Products Co.*

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be a major sales contributor in 1990.

However, they will apply downward pricing pressure on the lower-performance processor-based equipment.

The 68040 and i486 triple the performance of their 68030 and 80386 predecessors and are expected to be used for applications that previously were performed on mainframes and supercomputers. The i860 is designed for high-speed multiprocessing systems and 3-D graphics. □

## By 1992 EC technology will challenge the U.S.

IN LESS THAN 32 months the European Community's 12 countries and 320-million people officially become the second largest trading partner in the world. The EC's combined R&D also will take second place only to the U.S. in expenditures and talent.

That common R&D effort already is well under way. While such issues as banking and taxation will make the transition difficult, "the EC is set to function, particularly from a technological standpoint in 1992," says Catherine Morrison, director of public policy studies for the Conference Board, a New York business group.

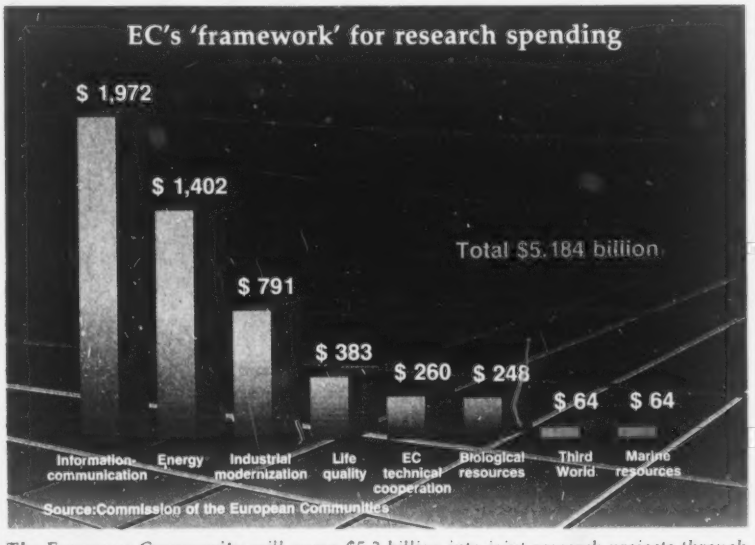
The EC's Framework Program for joint research and technological development has been in place for several years and has provided $5.2 billion in funding for the 1987-91 period. While this is a significant amount for community countries, it only accounts for 2% of all R&D activities in Europe, most of which is still national in nature.

Information technologies have the largest share (38%) of the allocations and promise to be the EC's dominant technology in the 1990s. Energy research (fission, fusion, nonnuclear, and nuclear safety, 27%) and industrial modernization (15%) also have high priority.

R&D for industrial competitiveness is managed within the Framework Program by such efforts as Esprit (information technology), RACE (advanced communications), Brite (industrial technology), and Euram (advanced materials).

The Framework Program is administered by the Council of Ministers, who recently expanded it with $610 million for industry and energy R&D programs for 1989 to 1992. The majority of this is follow-up funding for the Brite and Euram programs to support the EC's traditional manufacturing industries—automobiles, chemicals, textiles, and aircraft.

"Europeans currently view both the U.S. and Japan from a technological standpoint in the same manner as the U.S. now views the Japanese," says Morrison. The EC sees mergers, joint ventures, and alliances as the best way to be competitive, and has almost a 30% average annual increase in mergers and takeovers for the past five years.




***The European Community** will pump $5.2 billion into joint research projects through 1991. Another $610 million will go into industrial and energy R&D by 1992.*

The Japanese anticipate problems after 1992 in exporting to the EC. To circumvent this, they are establishing manufacturing facilities within the EC for internal sale and export to the U.S. and Japan.

The Japanese also are constructing R&D facilities within the EC to fully understand and relate to the local EC marketplace. □

## Supply-side labor—the next competitive crisis

THE GROWTH OF science and engineering (S&E) jobs in industry is expected to increase 35 to 45% from current levels by the year 2000. This growth rate is lower than the 1977 to 1986 period due to slowdowns in available labor force, total employment, and GNP, according to a projection prepared by the National Science Foundation.

Even with a lower demand, the supply of S&E workers for these positions will be dramatically restricted by the availability of college graduates.

The college-age population is shrinking—by 1996 there will be 25% fewer people in this age group than there are now. The combination of these demographics and a lessening of interest in S&E careers is already responsible for a decline in the overall number of S&E degrees being awarded. In one UCLA study, the percentage of freshman opting for engineering declined from 12% in 1982 to 8.5% in 1987.

This overall decline could persist until the mid-1990s, says Univ. of Washington's dean of engineering, J. Ray Bowen.

The increase in demand and decrease in supply is further aggravated by increased pressure from R&D sectors for personnel with advanced degrees to maintain competitiveness with foreign companies.

Manpower requirements for the technical staffing of U.S. facilities in foreign countries, the staffing of foreign-owned R&D centers in the U.S., and an increase in S&E retirees further eats into the labor supply.

This problem can be alleviated by increasing the minority representation in S&E graduates, says Bowen. Currently, three fourths of S&E bachelor degrees are awarded to white males. Minority levels for BS candidates are 15% women, 3% black, 3% Hispanic, and 6% Asian. The percentages are even lower for advanced degrees, according to Engineering Manpower Commission reports. **R&D**

# Keys to Top R&D Salaries: Age, Experience, Education

Sex differences remain in applied science salary picture, but at a lower level; industry-government-university trade-offs persist.

*By **Robert R. Jones**, Executive Editor, R&D magazine*

TO EARN the big salary in research and development, there is a simple formula: Be a 65-year-old male aeronautical engineer working in industry, with a PhD and 40 years' experience.

For the R&D scientist or engineer who may someday fit into the above formula, and even for those who won't, there is good news this year. Incomes in research and development are up, with an average real increase of 4% across all disciplines.

That, and other profile data about the R&D industry, including salary comparisons by disciplines and a discussion of the salary value of experience, were presented in the first part of this article (March, pages 44-47).

In this second part we will look at the salary benefits that apply to gender, amount of education, and workplace.

To begin with, 50% of the population is ruled out of the above high-salary formula by gender. Although its extent has been reduced in the past two decades, there still is sex discrimination in R&D salaries.

Along with that come factors which at first appear to be sex discrimination, but are merely sex/culture related. They lead to justifiable differences in men's and women's average salaries, but the women come out on the short end, none the less.

### Women and work experience

One sex/culture-related factor is the job experience that was shown earlier to be so valuable. Women who follow spouses who move to new jobs or who delay or interrupt their careers to rear children rarely can accumulate 40 years' experience in R&D—but one of the things R&D pays for is experience.

Specifically, only 11.9% of the women responding to this survey have more than 25 years' experience in R&D, while 63.2% of the respondents earning more than $85,000 per year have more than 25 years' experience.

Also sex/culture related is the fact that a large portion of women scientists are in biology and a large portion of biologists are in universities.

The combination of female, university, and biology contrasts sharply with the male aeronautical engineer in industry. (Female, university, and mathematician or industrial engineer might be worse, but there are too few of them for our sample to identify.)

Even having a PhD in her field does not make enough salary difference to bring the female university biologist into the upper salary ranks.

### Those higher degrees

The large figures that the R&D industry associates with PhD salaries got bigger during the past year. The median salary of PhD respondents to this survey increased by 7.8% to $54,351 from last year's $50,995. This amounts to an increase of more than 25% in five years.

The average R&D scientist or engineer with a doctoral degree now can expect a career advantage of $1,825,000 over his R&D colleague who did not go beyond the baccalaureate level.

The spread in average PhD over BS career earnings has nearly tripled in the past five years from $620,000 in 1984.

Respondents to this survey have made it clear that the net value of a PhD over a BS depends on an individual's field of endeavor and gender, and whether the employer is from industry, academia, or government.

When allowance is made for the fact that the above PhD benefits are based on the median for our respondents, it is easy to see that many PhDs will realize much larger benefits from their doctorates.

The $1,825,000 career benefit figure is what remains after we deduct costs of additional education and allow for the extra years spent in school.

We assume that the holder of the PhD will work 35 years after getting that degree, a figure that our survey shows is fully believable. We allow a 40-year career for the person who enters the work force after getting a BS.

Assuming an 8% interest rate prevailing over the 35-year career of the PhD and allowing $300,000 for tuition, missed earnings, etc., we then can make appropriate projections. From this, comes the PhD's career benefit figure.

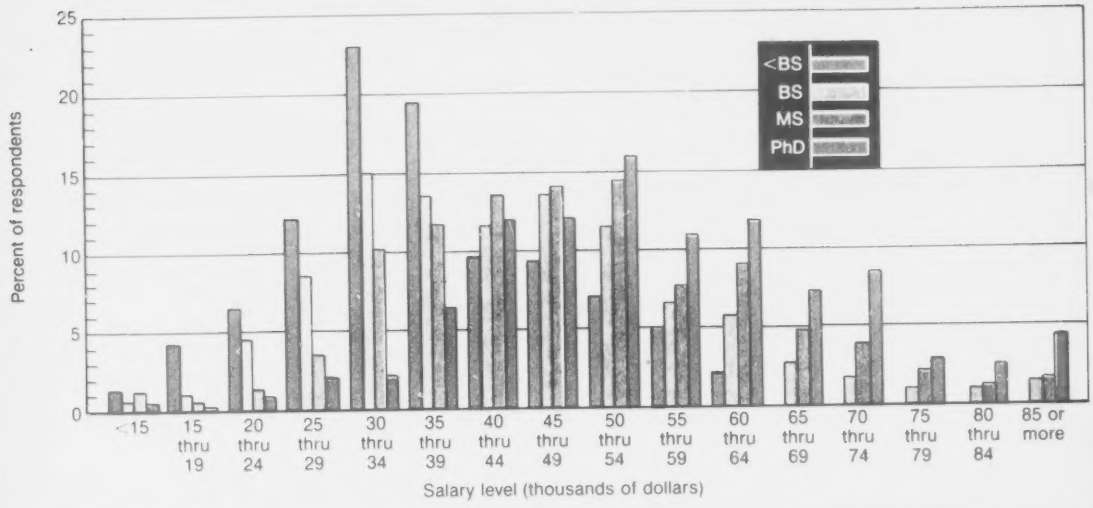
Using similar calculations with different allowances for earning years and expenses, we find that the present career value of a PhD over an MS is just under a million dollars, only a small change from last year's figure, but up from $370,000 five years ago.

### Get that degree!

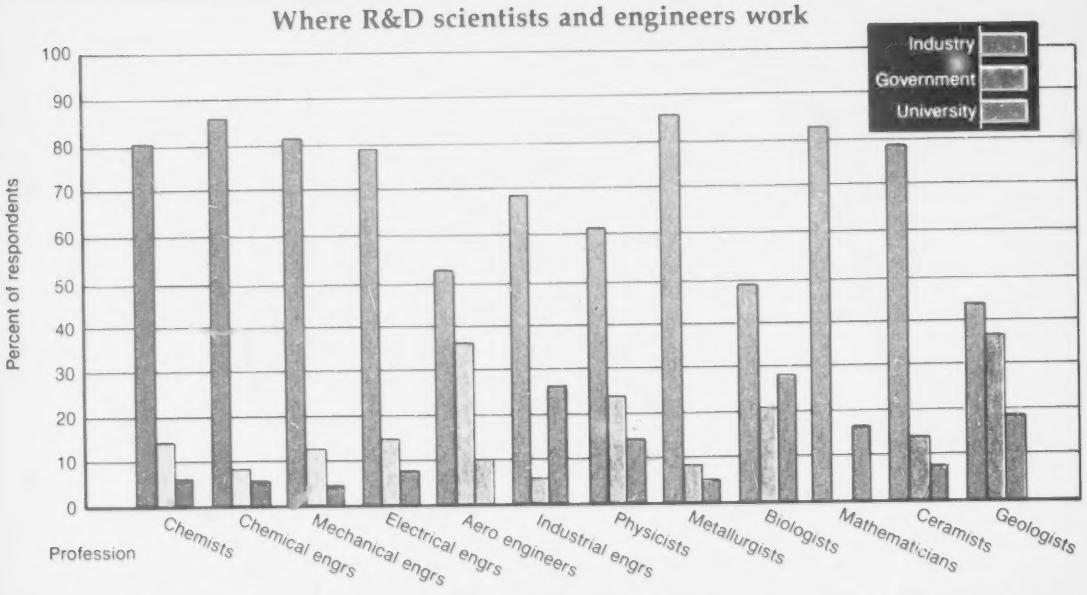
For this year's crop of new high school graduates who may be uncertain about the value of a college degree, the message in this survey is obvious: Get the degree.

Respondents report that the net ca-

## How 1989 salaries reflect level of education




## Where R&D scientists and engineers work




## Median salaries by sex and workplace

| | 1989 | 1988 | % change |
|---|---|---|---|
| Men in industry | $49,434 | $45,111 | + 9.6 |
| Men in government | 45,802 | 42,667 | + 7.3 |
| Men in universities | 44,317 | 41,635 | + 6.4 |
| Women in industry | 36,561 | 35,543 | + 2.9 |
| Women in government | 41,249 | 33,500 | + 23.1 |
| Women in universities | 27,499 | 27,083 | + 1.5 |

## Median salaries all R&D by workplace

| | 1989 | 1988 | 1987 |
|---|---|---|---|
| Industry | $48,307 | $44,175 | $43,887 |
| Government | 45,482 | 41,786 | 42,200 |
| University | 43,181 | 40,250 | 38,621 |

## Getting a PhD *vs* no college degree can be worth an added $3,030,000 over a 35-year career.

| | 1988 salary raise, amount | | | | | | 1989 salary range | | | Years with present employer | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | None (%) | Less than 2% (%) | 2 thru 5% (%) | 6 thru 9% (%) | 10 thru 13% (%) | 14% or more (%) | Median | <$15,000 (%) | >$85,000 (%) | Median | <1 (%) | >36 (%) |
| Aeronautical engineer | 6.7 | 16.7 | 66.7 | 10.0 | — | — | $57,500 | — | 3.3 | 17.00 | — | — |
| Biologist | 4.9 | 4.9 | 51.0 | 29.4 | 5.0 | 4.8 | 43,846 | — | 2.9 | 8.86 | 2.9 | 1.0 |
| Ceramist | 6.9 | 3.4 | 65.5 | 20.7 | — | 3.4 | 50,500 | — | 3.4 | 5.06 | 3.4 | — |
| Chemical engineer | 10.1 | 3.6 | 62.6 | 16.5 | 5.0 | 2.2 | 49,100 | — | 2.9 | 8.30 | 2.9 | 2.2 |
| Chemist | 9.4 | 3.9 | 54.7 | 21.9 | 6.6 | 3.5 | 45,243 | 0.3 | 2.0 | 8.84 | 3.0 | 0.5 |
| Electrical engineer | 11.7 | 6.2 | 51.2 | 22.8 | 4.9 | 2.5 | 50,185 | 1.9 | 2.5 | 10.63 | 1.9 | — |
| Geologist | 15.6 | 12.3 | 47.7 | 16.5 | 7.9 | — | 50,500 | 4.5 | 3.5 | 7.75 | — | — |
| Industrial engineer | 5.1 | 5.5 | 63.2 | 15.8 | 5.4 | 5.2 | 38,125 | 5.3 | — | 9.75 | — | — |
| Mathematician | — | 0.4 | 32.9 | 34.4 | 32.2 | 0.1 | 42,500 | — | — | 6.33 | 7.4 | — |
| Mechanical engineer | 9.9 | 4.2 | 50.2 | 25.4 | 8.5 | 1.9 | 48,900 | 0.5 | 0.9 | 8.46 | 3.8 | 0.9 |
| Metallurgist | 11.5 | — | 59.8 | 23.0 | 5.7 | — | 52,205 | 1.1 | — | 9.75 | 2.3 | — |
| Physicist | 6.0 | 11.9 | 56.7 | 21.6 | 3.0 | 0.7 | 51,087 | — | — | 9.67 | 6.0 | — |

## 1989 profile of the research and development industry

**What is your annual salary?**

| | |
|---|---|
| Less than $15,000 | 0.8% |
| $15,000 to $19,999 | 0.9 |
| $20,000 to $24,999 | 2.7 |
| $25,000 to $29,999 | 5.6 |
| $30,000 to $34,999 | 10.5 |
| $35,000 to $39,999 | 11.3 |
| $40,000 to $44,999 | 12.0 |
| $45,000 to $49,999 | 12.8 |
| $50,000 to $54,999 | 13.3 |
| $55,000 to $59,999 | 7.9 |
| $60,000 to $64,999 | 8.1 |
| $65,000 to $69,999 | 4.4 |
| $70,000 to $74,999 | 4.2 |
| $75,000 to $79,999 | 1.8 |
| $80,000 to $84,999 | 1.4 |
| $85,000 or more | 2.2 |

**Your raise during the past year was**

| | |
|---|---|
| None | 9.3% |
| Less than 2% | 5.3 |
| 2 through 5% | 54.8 |
| 6 through 9% | 22.2 |
| 10 through 13% | 5.6 |
| 14% or more | 2.7 |

**How long have you worked for your present employer?**

| | |
|---|---|
| Less than 1 year | 3.5% |
| 1 through 3 years | 16.3 |
| 4 through 6 years | 16.6 |
| 7 through 9 years | 15.2 |
| 10 through 12 years | 8.4 |
| 13 through 15 years | 8.1 |
| 16 through 18 years | 5.7 |
| 19 through 21 years | 6.8 |
| 22 through 24 years | 6.2 |
| 25 through 27 years | 4.3 |
| 28 through 30 years | 3.4 |
| 31 through 33 years | 3.4 |
| 34 through 36 years | 1.5 |
| More than 36 years | 0.6 |

**What is your age?**

| | |
|---|---|
| Under 26 years | 1.9% |
| 26 through 30 years | 9.5 |
| 31 through 35 years | 14.1 |
| 36 through 40 years | 16.3 |
| 41 through 45 years | 15.6 |
| 46 through 50 years | 13.3 |
| 51 through 55 years | 11.5 |
| 56 through 60 years | 11.2 |
| 61 through 65 years | 4.2 |
| Older than 65 years | 1.9 |

**How many years of experience do you have?**

| | |
|---|---|
| Less than 1 year | 0.3% |
| 1 through 5 years | 11.6 |
| 6 through 10 years | 15.6 |
| 11 through 15 years | 16.5 |
| 16 through 20 years | 14.8 |
| 21 through 25 years | 12.7 |
| 26 through 30 years | 11.7 |
| 31 through 35 years | 9.8 |
| 36 through 40 years | 5.1 |
| More than 40 years | 2.1 |

**What is the highest degree you hold?**

| | |
|---|---|
| Less than bachelor | 8.1% |
| Bachelor | 35.2 |
| Master | 25.3 |
| Doctorate | 31.3 |

**What is your profession?**

| | |
|---|---|
| Chemist | 34.9% |
| Chemical engineer | 8.1 |
| Mechanical engineer | 12.5 |
| Electrical engineer | 9.6 |
| Aeronautical engineer | 1.8 |
| Industrial engineer | 1.1 |
| Physicist | 7.8 |
| Metallurgist | 5.1 |
| Biologist | 6.0 |
| Mathematician | 0.4 |
| Ceramist | 1.7 |
| Geologist | 1.5 |
| Other | 9.5 |

**Do you work in . . .**

| | |
|---|---|
| Industry | 76.2% |
| Government | 14.5 |
| University | 9.2 |

**Are you . . .**

Male . . 90.6% Female . . . 9.4%

| Age, years | | | Experience, years | | | Highest academic degree | | | |
|---|---|---|---|---|---|---|---|---|---|
| Median | <26 (%) | >65 (%) | Median | <1 (%) | >40 (%) | <BS (%) | BS (%) | MS (%) | PhD (%) |
| 47.14 | — | 13.3 | 27.00 | — | 16.7 | — | 51.0 | 36.7 | 12.3 |
| 40.25 | — | — | 15.12 | 1.0 | — | 2.0 | 12.7 | 24.5 | 59.8 |
| 37.81 | — | — | 14.58 | — | — | 3.4 | 13.8 | 42.6 | 40.2 |
| 40.19 | 1.4 | 2.2 | 14.33 | — | 2.2 | 1.4 | 42.4 | 31.7 | 24.5 |
| 42.56 | 1.0 | 1.3 | 16.87 | 0.2 | 1.3 | 4.4 | 37.2 | 19.5 | 38.9 |
| 43.91 | 2.8 | 3.4 | 20.71 | — | 2.5 | 14.8 | 43.8 | 31.5 | 9.9 |
| 46.50 | — | 4.0 | 18.75 | — | 4.2 | — | 19.1 | 36.7 | 44.2 |
| 48.12 | — | — | 20.50 | — | — | 31.6 | 21.1 | 32.4 | 14.9 |
| 40.10 | — | — | 8.33 | — | — | — | 48.7 | 17.9 | 33.4 |
| 41.46 | 4.2 | 1.9 | 16.54 | 0.9 | 2.3 | 12.7 | 43.7 | 31.5 | 12.2 |
| 44.77 | 2.1 | 2.5 | 19.79 | — | 1.1 | 6.9 | 40.2 | 21.8 | 31.0 |
| 45.21 | 2.2 | 1.5 | 18.86 | 0.7 | 1.5 | 0.7 | 22.4 | 26.1 | 50.7 |

reer benefit for a BS over less-than-BS is $1.2 million.

Entirely separate from the personal benefits that accompany a bachelor degree, the extra two, three, or four years that might be necessary to go from less-than-BS to having the diploma would return to a typical individual a minimum of $300,000 per year invested.

Adding the MS to a BS is worth another $825,000 over a career, or roughly $23,000 additional income in each year of the career.

There are other interesting and helpful comparisons that can be drawn from this survey of salaries in relation to the highest academic degree as you will see in the accompanying table.

As has been true in recent years, the income advantages of baccalaureate and advanced degrees again increased as fast or faster than the rate of inflation. However, the median income for respondents with less than BS did not keep up with inflation.

One result of this situation is that the median advantage of a PhD over less-than-BS in annual income increased to $18,704. Thus the career income benefit for the individual with a PhD degree over the one with no degree rises to an astounding $3,030,000, or nearly $86,000 for each year of the career.

The career difference for PhD over no degree has increased by more than 20% in just two years, having been $2,480,000 in the 1987 survey.

### Who has the degrees?

Advanced degrees are much more common in some disciplines than in others. Biologists lead the R&D industry in PhDs with 59.8%, up from 56.0% last year and 52.0% in 1987.

Physicists rank second with PhDs among this year's respondents at 50.7%, up from 49.0% last year; geologists are third with 44.0%, down from 51.5% last year; and ceramists are 4th-high at 41.4%, unchanged from last year.

Electrical engineers report the fewest PhDs, with 9.9%.

Looking at total advanced degrees, masters plus PhDs by disciplines, biologists retain their leadership with 84.3%, an increase from 72.5% last year; ceramists are second at 82.8%, having had 69.0% last year; and geologists, at 80.0%, are down from 84.8% last year.

Electrical engineers count the fewest advanced degrees with 41.4%. Next-low are the mechanical engineers at 43.7%.

As a final comment about numbers of advanced degrees, it should be mentioned that last year's report pointed to the fact that "for some reason, possibly because of early retirement programs, the portion of respondents with PhD degrees in our annual survey has been declining in recent years."

After climbing to 33.1% in 1985, the PhD portion dropped to 30.1% in 1986 and 28% in 1987. The number moved very little last year, rising only to 29.2%. For this year's respondents, however, the figure stands at 31.3%, close to where it had been in earlier years.

### Those who earn less

Reference was made earlier to the fact that these are all median figures, and that many PhDs will earn substantially more than the figures cited. By the same token, there will be some who earn substantially less, and a large portion of these will be women.

This result can be seen in the table showing salary by sex and workplace. Also notable in that table is the large increase in median salary this year for women who work in government.

In 1985, the median annual income for women working in government research and development was higher than the figure for women in industry. The median for this group fell in 1986, remained level in 1987, and by last year had returned to the 1985 level.

With this year's results, the salaries of women who work in government R&D again are ahead of those in industry. However, as the table clearly shows, the highest median salary for women in R&D (in government) remains below the lowest median for men (in universities). The difference is more than 7%.

Eventually, that may change. Over a number of years this annual survey has shown that women are doing a little better than men do when it comes time for salary increases.

From the last table in this article it can be shown that 40.7% of women respondents received salary increases last year that were equal to or higher than the rate of inflation. Only 29.7% of the men did as well.

The corresponding figure for women last year was 35.6%.

### Job longevity

For many years, it was safe to say that nothing helps a person move up the corporate ladder in R&D like being with one organization for a long time.

While this is akin to years of experi-

## In a year of change, many R&D industry trends have wavered or turned in new directions.

### R&D salaries compared by academic degrees

| Degree | Median salary 1989 | Median salary 1988 | Percent change | Annual difference* 1989 | Annual difference* 1988 | Difference change (percent) |
|---|---|---|---|---|---|---|
| Doctorate | $54,351 | $50,955 | +7.8 | $6,436 | $6,350 | + 1.3 |
| Master | 47,915 | 44,605 | +7.4 | 4,982 | 5,537 | −10.1 |
| Bachelor | 42,933 | 39,068 | +9.9 | 7,286 | 4,837 | +50.6 |
| <Bachelor | 35,647 | 34,231 | +4.1 | | | |

*Difference above next lower degree

### Percent receiving R&D salary increases by sex

| Amount of increase | Granted in 1988 Male | Granted in 1988 Female | Granted in 1987 Male | Granted in 1987 Female |
|---|---|---|---|---|
| None | 10.0 | 3.1 | 14.5 | 14.1 |
| Less than 2% | 5.3 | 5.6 | 6.6 | 4.0 |
| 2 through 5% | 54.9 | 50.6 | 50.1 | 46.3 |
| 6 through 9% | 21.4 | 31.9 | 21.3 | 24.9 |
| 10 through 13% | 5.7 | 4.5 | 4.6 | 6.2 |
| 14% or more | 2.6 | 4.3 | 2.9 | 4.5 |

ence, in some organizations it seemed to be even more important. The chart of salary for years with present employer rose as consistently with the passage of time as did the chart of salary for experience.

Now things have changed. There are new companies marketing new products in new ways. Mergers and acquisitions have blurred old seniority patterns and company loyalties.

No longer is it advantageous merely to have stayed with the same company for 15 or 20 years. That is, longevity is not a salary asset in and of itself.

This can be seen in the data from those respondents reporting salaries of $50,000 per year or more in this year's survey.

Dividing those respondents into two groups, those who have been with their present employer less than 10 years and those who have worked for the same employer between 10 and 20 years reveals that 55% had been with their present employer less than 10 years and only 45% are in the higher longevity group.

Men working in research and development are more likely to fill the traditional longevity role than are women, and reasons for this have been mentioned.

Among this survey's respondents, 23.6% of the men have worked for the same employer more than 18 years, compared to only 13.2% of the women being with the same employer more than 18 years.

Detailed comparisons for research and development workers by their disciplines are made in the large table accompanying this article. It shows range and median for four categories of information and percent distribution for two other catagories for each discipline.

Complete results of this year's Profile of the Industry survey are shown in the other large table.

### Reversing the trends

It should be noted that last year's Profile of the Industry pointed to what seemed at the time to be a significant number of downward trends in important parameters. These were slippages which, it was suggested, could presage serious problems for the R&D industry.

One is almost tempted to ask whether mentioning those trends was all that was needed to reverse them.

Be that as it may—without exception—every trend which was cited as a possible cause for concern last year has been reversed this year.

One cause for concern was the possibility that the R&D work force was losing its experienced workers and they were being replaced with entry-level workers.

This concern was fostered by these developments:

- The portion of respondents with less than one year's experience had increased steadily to 0.6% last year. (It fell to 0.3% this year.)
- The portion with less than 6 years' experience had climbed to 12%. (It fell to 11.9%.)
- At the same time, the portion of respondents with more than 35 years' experience had declined by more than a fifth, from 6.8% to 5.4%. (It hit 7.2% this year.)
- As regards time with present employer, the portion with fewer than 4 years had risen dramatically by a sixth in three years to 21.0%. (It dropped even more dramatically to 16.3% this year.)
- Another clue to a younger and inexperienced work force was the fact that the portion of respondents earning less than $25,000 per year had moved resolutely to 7.7%. (It now is at 4.4%.)
- Respondents who were younger than 31 years of age had increased until the portion hit 13.2% last year. (Now 11.4%.)
- And the final cause for concern was the fact that the median salary for all R&D workers had been increasing at a decreasing rate of 6.3%, 3.2%, 4.3%, and 0.42% in succeeding years. A dip into the negative seemed almost certain.

However, it didn't happen. As has been mentioned earlier, this year's survey revealed the largest median salary increase for R&D in a number of years, 9.25%.

The listing of these causes for concern in last year's report was followed by the statement, "Most of the above changes are small, hardly worthy of mention by themselves, but when there are so many changes happening at the same time it is hard to say that they hold no significance."

Now it can be said: They held no significance. R&D

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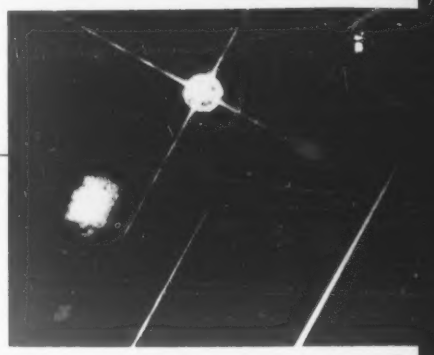


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# Microlasers Offer New Reliability for R&D

Efficient solid-state microlasers in industry and R&D labs can attack problems other lasers can't address.

*By Philip E. Chumbley, Amoco Laser Co.*

R&D

THE AUTHOR

**Philip E. Chumbley** is product manager at Amoco Laser Co., Naperville, IL. Previously he was manager of production and manufacturing and did research with the integrated materials group. Chumbley received a BS in engineering physics at Univ. of Illinois, Champaign-Urbana, and a PhD in physics from Univ. of Missouri, Columbia.

FIRST, THROW the laser against the wall. Next, kick it across the floor. Now stomp on it a few times. Then pick it up; slip it into a laser mount; plug it in; turn it on; and use it to make sensitive measurements that require excellent beam profile, high stability, and low noise. . . .

Are we dreaming? No. Not if the laser is a microlaser.

Microlasers represent a new class of miniaturized, all-solid-state laser devices based on the emerging technology of diode-laser pumping of a solid-state crystal. The advantages of these new products range from improved performance that has been unattainable with many earlier lasers to greater ease of manufacturing the products.

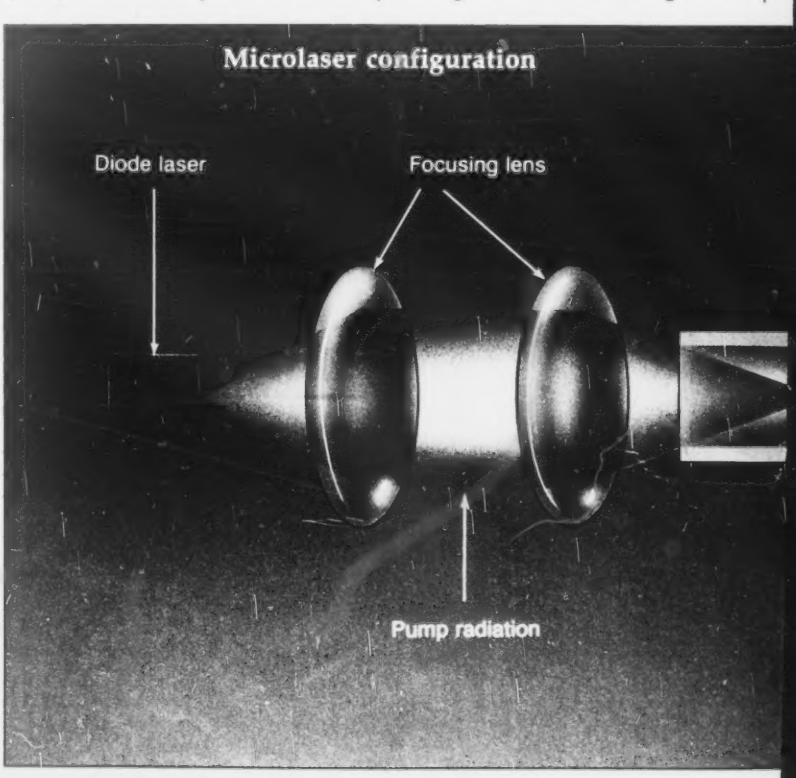
Compared to gas-discharge lasers, microlasers offer greatly improved efficiency, reliability, and compactness. These advantages permit microlasers to address research and industrial problems that cannot be served by conventional laser technology.

Examination of the projected 1989 laser market showed that diode lasers make up the largest single category (1). Nevertheless, total laser sales include large numbers of systems based on gas-discharge technology.

Examples are helium-neon (HeNe) lasers, which employ a gas-filled tube for the laser cavity. Also included are the flashlamp-pumped solid-state lasers such as yttrium-aluminum-garnet (YAG). Other examples are helium-cadmium, carbon dioxide, and argon-ion lasers.

In fact, until the advent of the diode laser, virtually every laser sold was based on gas-discharge technology. Sales of these gas-discharge lasers amounted to more than $400 million in 1988 (2).

Still, gas-discharge technology suffers from several built-in problems. One of these is the reliance on a gas-filled glass tube that is fragile—the



manufacture of which is labor intensive. Lifetimes of these glass tubes typically are a few thousand hours or less.

It is difficult to fabricate small glass tubes that can meet pressure and durability requirements. Therefore, most of the tubes have bulky shapes and must be carefully packaged to avoid breakage.

Even in solid-state lasers, which use durable solid-state crystals for the gain medium, the durability is compromised when glass-tube flashlamps are included as pump sources.

To implement gas-discharge technology, it also is necessary to generate high voltages (usually >1,000 V) to cause an electrical discharge in the gas.

To make matters worse, electrical-to-optical efficiencies range from 0.02% for a HeNe laser to 0.002% for an argon-ion laser—and even lower for HeCd lasers and others. Even solid-state lasers, such as YAGs, have efficiencies of only 0.1% when they are flashlamp-pumped.

Microlasers, on the other hand, offer all-solid-state construction. In a typical microlaser configuration, the pump source is a semiconductor diode laser that is focused into a solid-state crystal such as YAG or yttrium lithium fluoride.

Unlike flashlamps, which emit across a broad spectrum, the narrow output of the diode laser can be temperature-tuned to match the absorption bands of the lasing crystal. This technique yields electrical-to-optical efficiencies approaching 10%.

In addition, lifetimes for the pump diode lasers vary from 20,000 to 40,000 hr, compared to about 7,000 hr for a HeNe tube (3).

The absence of a glass tube makes the microlaser rugged and compact. The diode-laser pump source can withstand severe mechanical shock and is much smaller than a flashlamp.

In turn, the high absorption of pump radiation achieved by tuning the pump output to match the absorption bands in the gain medium allows the use of a smaller solid-state crystal than otherwise would be needed. This, of course, permits an additional decrease in size. Hence, the term *microlaser*.

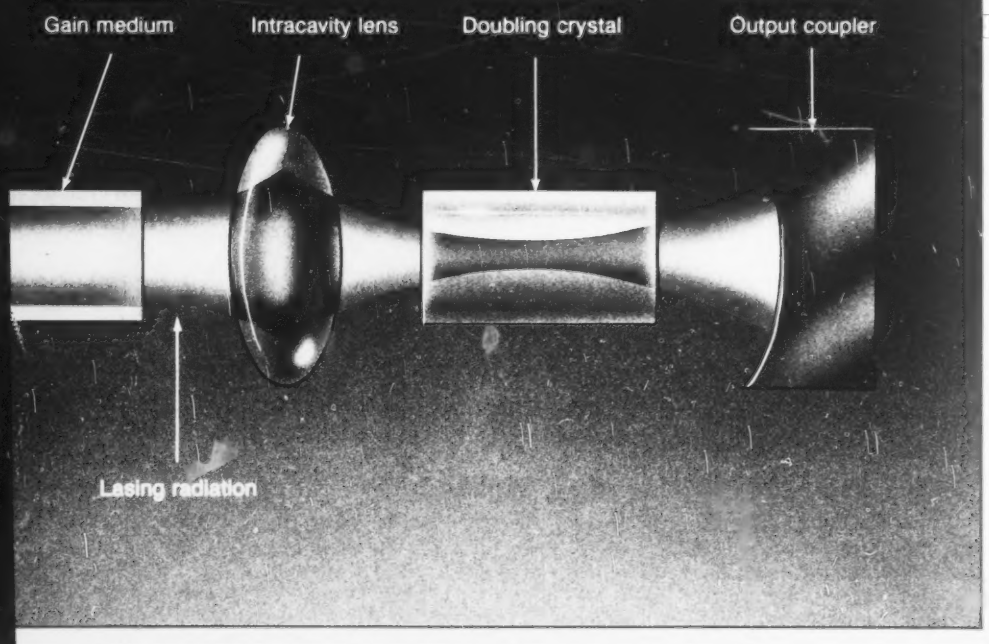
The reduction in package size results in additional advantages. A shorter laser cavity has faster rise times and will support fewer longitudinal modes than will a conventional laser.

Furthermore, mirror-alignment tolerances are not as critical as they would be in a longer cavity. Thus, manufacturing of the microlasers is easier, and the new devices are less sensitive to mechanical shock than are conventional lasers.

### Frequency doubling

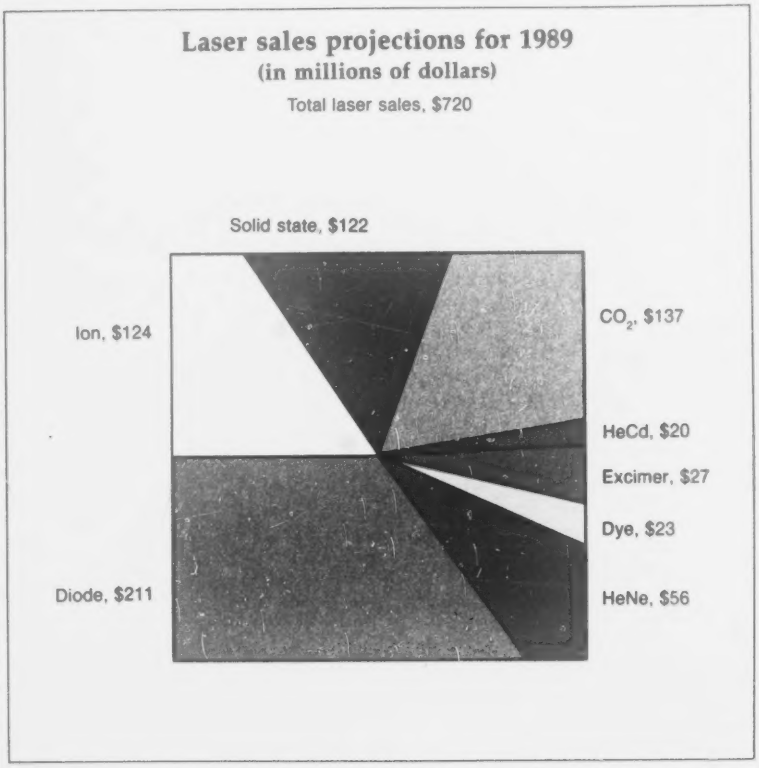
The introduction of an intracavity frequency-doubling crystal permits a microlaser that ordinarily emits radiation in the infrared region to produce visible light. By using different laser host materials coupled with various solid-state doubling crystals, the experimenter can obtain laser outputs that span the entire visible spectrum.

For example, intracavity doubling of a YAG microlaser that operates at 1,064 nm produces green light at 532




*In a microlaser, the narrow output of the diode pumping laser can be temperature-tuned to provide efficiencies approaching 10% vs 1% for gas-discharge lasers.*

## Frequency doubling of lasing wavelengths can produce new, shorter wavelengths.




*The laser market for 1989 is dominated by diode lasers as the single largest category, but total laser sales still depend heavily on gas-discharge technology.*

nm. A different YAG laser that operates at 1,320 nm can be frequency doubled to give red light at a frequency of 660 nm.

In these two examples, the solid-state materials are the same; the only differences are the mirror coatings and the crystal orientation of the doubling crystal. That is, chemically identical materials have produced lasers with two totally different wavelengths, red and green.

Intracavity doubling allows multiple passes of the fundamental-frequency photons through the crystal. This capability results in a higher conversion efficiency than would be possible if the doubling crystal were placed outside the cavity.

In a similar manner Brewster plates can be added inside the cavity to provide polarized output with minimal loss of intensity, compared to a 50% intensity loss when unpolarized light is passed through an external polarizer.

Since microlasers are pumped by diode lasers, relatively high-powered microlasers can be obtained simply by inserting a high-powered diode laser. At the present time, diode lasers with output power greater than 1 W are available, and powers greater than 10 W will be attainable in the near future. In addition, it is possible to directly modulate diode lasers—something that cannot be done easily with gas-discharge tubes.

Often, laser users will ask: Why should we pump a solid-state crystal with a diode laser? Why not simply use the diode laser itself? The answer lies in the beam quality and in the ability of the laser to reach different wavelengths.

Microlasers produce Gaussian beams (*i.e.*, the beam intensity observed across the beam follows a standard distribution curve), while the intensity observed across a diode-laser beam shows alternate high-intensity and low-intensity zones. This Gaussian ($TEM_{00}$) diffraction-limited beam readily accepts frequency doubling, or summing, through the crystal.

Since different fundamental wavelengths are available through the use of various host crystals, frequency doubling of the lasing wavelengths can produce new, shorter wavelengths than have been available with other systems.

### Manufacturing microlasers

One of the major advantages of microlasers is the fact that these devices can be readily made by high-volume manufacturing techniques.

Historically, the laser marketplace has been divided into a large number of segments, with a correspondingly large number of laser products designed to address these segments. This segmentation of laser products, each of which occupies its own small niche in the industry, has discouraged the development of high-volume, low-cost manufacturing techniques such as those found, for example, in the electronics industry.

In the manufacture of microlasers, however, the solid-state crystals and the optics are physically identical, except for the optical coatings. Thus, these components can be interchanged to produce microlasers that emit radiation at different wavelengths.

In the green and red frequency-doubled examples described earlier, the two microlasers look identical. Therefore, manufacturers can use the same techniques to produce totally different products. This continuity of manufacturing for a wide variety of products results in high-volume production at reduced cost.

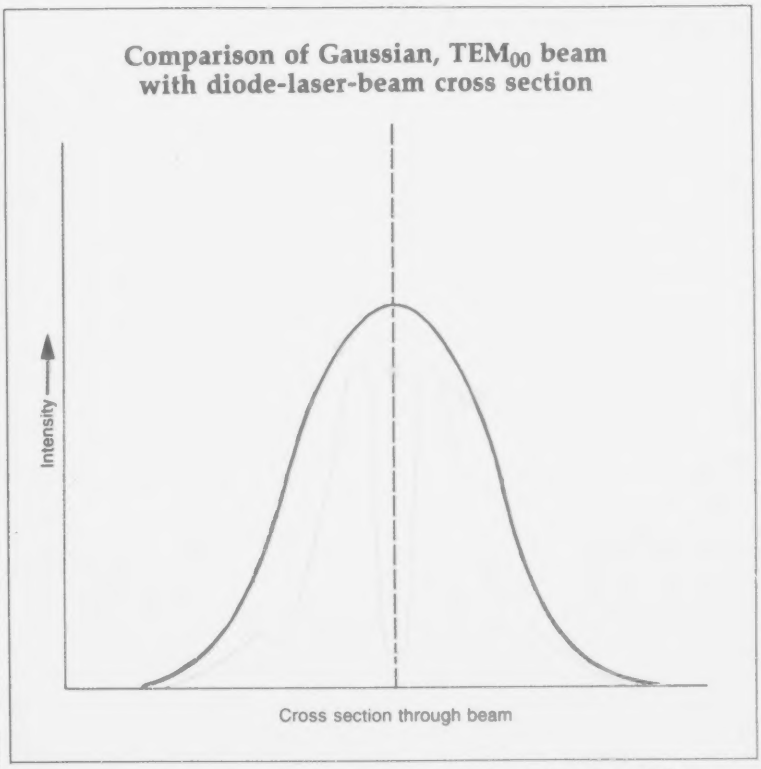
### Microlaser applications

Listing applications for microlasers is like trying to list applications for the transistor when it first was introduced into the electronics industry. The obvious application is as a replacement technology, *i.e.*, microlasers for gas-discharge lasers, just as transistors replaced vacuum tubes.

Yet the real promise lies in applications that do not exist today but will be made possible by microlaser technology. Small size, high efficiency, and ruggedness will allow microlasers to address applications that previously were denied to the laser industry.

Meanwhile, here are a few of the

## Microlaser applications include microsurgery, telecommunications, and optical alignment.




***Microlasers produce a Gaussian beam** that is conducive to frequency doubling through the crystal, allowing the solid-state lasers to offer new, short wavelengths.*

present-day applications open to penetration by microlasers:

• Testing and inspection. Compact, highly reliable microlasers can be used in harsh manufacturing environments for testing and inspection of optical components, thin films and coatings, optical fibers, and semiconductor devices.

• Optical alignment. Small, efficient microlasers can be used to align large, complex, high-powered laser systems of the same wavelengths that are used in medical, military, industrial, and R&D applications.

• Materials characterization. The high stability, low noise, and high beam quality of microlasers allows rapid, reliable characterization of solid-state crystals, semiconductor materials, and gases.

• Micromachining and microsurgery. The diffraction-limited output of microlasers allows them to be focused to beam diameters less than 5 μm. The resulting power density in the focused spot can exceed $10^6$ W/cm$^2$. This is sufficient to melt or vaporize many materials.

• Telecommunications. The small size, reliability, and available wavelengths of microlasers, together with their ultralow noise, make these devices useful for data transmission, especially in fiber-based systems. While the modulation rate of YAG laser systems is limited to about 100 MHz, the frequency-summing techniques available in microlasers extend the modulation rate into the GHz range (4).

• Research and development. Flashlamp-pumped YAG lasers are basic tools in university, industry, and government R&D labs throughout the world. In these labs, compact, efficient, inexpensive microlasers can address many of the applications now being served by large, bulky gas-discharge lasers. In addition, improved stability and low noise make microlasers attractive in these areas.

• Optical storage. Short wavelengths with a diffraction-limited beam, plus low noise, make microlasers ideal for laser writing and reading of information on an optical disk (5).

• Military applications. The compact size, reliability, and ruggedness of microlasers allow their use as range finders, target designators, and instrument alignment devices.

• Entertainment. The small size, reliability, and excellent beam quality of visible-light microlasers will be important in projection television, film writing, and laser-signal transmission.

### Where do we go from here?

The future of microlasers lies in developing new wavelengths and higher powers. In our lab, we have identified at least 20 different wavelengths suitable for microlaser construction. Continued research on new materials promises to identify even more wavelengths. For example, green, red, and blue microlasers already have been developed—as have polarized, Q-switched, and single-mode models.

In addition, high-power diode lasers, now being developed in several laboratories around the world, will allow increased output powers. With increases in power and range, microlasers can replace even more of the gas-discharge types in use at present, and they will create new applications that are limited only by the imaginations of the people who introduce microlaser technology to new fields. **R&D**

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PRODUCT UPDATE—NICOLET'S SYSTEM 500

# New Power in Waveform Acquisition and Analysis

## Unique software helps make the System 500 "turn-key" ready

At first glance, Nicolet Instrument's unveiling of its new System 500 seems newsworthy because of the 500's industry-leading hardware. Indeed, in the world of waveform aquisition and analysis, where more is better, the System 500 is in a class by itself. The 500 has more channels, more memory, more speed and more resolution.

Each digitizer board, with its own independent trigger circuitry, time base and up to 1 megasample record length, is worthy of a full review. This multi-channel system can be configured to have as many inputs you need — up to several hundred. The digitizer boards are designed to be the equivalent of having a 12 bit digital scope on a card.

### Turn-key system

But after you get your hands on the System 500, the the most important news becomes apparent. Someone has finally developed a very powerful, competitively priced system for waveform aquisition and analysis that truly is a "turn-key" system.

You literally can take this system out of the box, plug in the power cord, connect the GPIB cable between the aquisition unit and the controller, and turn it on. The System 500 is now ready to take data. This turn-key readiness promises to save time by considerably reducing the learning curve needed to perform complex waveform aquisition and analysis.

### Intuitive windows software

The primary reason for System 500's easy operation is Nicolet's unique software which operates under Microsoft Windows/386™. The powerful Nicolet software can easily be controlled through pulldown menus that can be accessed by mouse or keyboard.

Measuring waveforms becomes as simple as pointing to the data point of interest on a waveform and clicking the mouse — the voltage and time values for the selected point is immediately displayed on the screen. By using the Delta Numerics function relative measurements like peak to peak or rise time can easily be made.

Also, Nicolet's unique software, combined with the System 500's built–in processor and co-processor, make incredibly fast waveform processing and analysis possible.

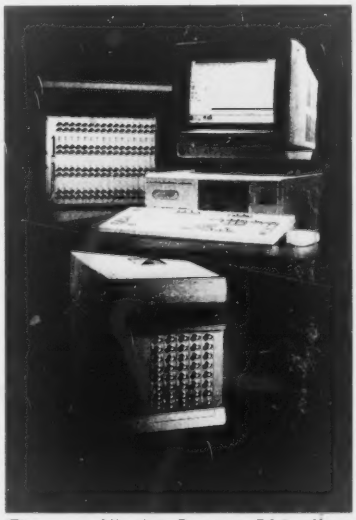
### Local processing

While other data aquisition systems need to transfer data to another computer for analysis, Nicolet has built calculation capabilities into the new System 500. Complex calculations can be performed on acquired data as it resides in the digitizer's memory.

There is no need to transfer data to a computer for analysis, no need for complex programming to handle normalizing sets and long record lengths. Functions are performed on the powerful 32 bit processors with a few clicks of the mouse. This local processing of data greatly decreases the time it takes to generate answers.

The bottom line is that the System 500 is a unique turn-key waveform acquisition system. For full details you'll need to read the product brochure.

***Call Nicolet Test Instruments (800) 356-3090***



The new Nicolet System 500 offers multi-channel flexibility with up to 10 MegaSamples/Second digitizing rates.

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ABP BPA ABC

# R&D

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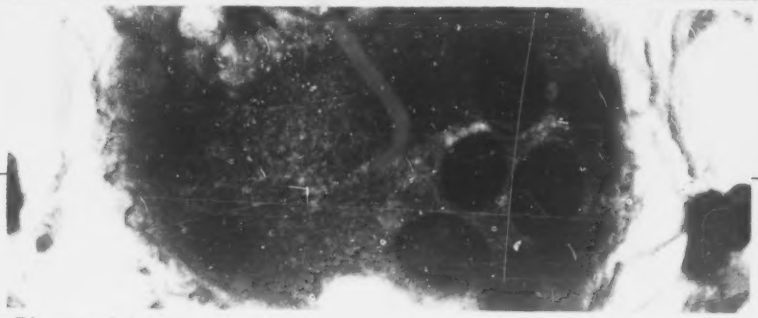

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## Intellectual properties need global protection

A COMPANY'S PATENTS and trade secrets are critical to its success in domestic and world markets. However—

- protection of intellectual properties can vary greatly from country to country, and
- U.S. court rulings now heavily favor support of patents.

The need to protect intellectual properties is more pressing than ever due to increased global competition, counterfeiting problems, and the development of new technologies, such as advanced microelectronics and genetic engineered materials.

Many countries, especially those undergoing development, are reluctant to recognize or enforce intellectual property rights. Brazil, Indonesia, and India, for example, have virtually no patent or trademark laws. Taiwan, China, and Korea punish hard goods counterfeiters with a slap on the wrist. A few countries can inflict huge losses on U.S. industries (see table).

Even Japan often is listed among those countries that fail to enforce intellectual property rights—a sore point in Japan-U.S. trading relations.

To counter increasing U.S. demands for trade concessions, Japanese companies recently have expanded their property protection capabilities.

Within the past year, Mitsubishi Electric Co., Sharp Co., Toshiba Corp., Matsushita Electric Industrial Co., and Hitachi Ltd. have reorganized, enlarged, or set up substantial intellectual property departments in their Japanese headquarters. These companies already receive large numbers of U.S. patents. Their recent efforts should increase those numbers.

As for the U.S. legal system's about-face on patent protection, one measure is the size of recent judgments, such as the multibillion-dollar award Polaroid obtained from Kodak for patent infringement. This reverses the judiciary's attitude of less than 10 years ago when judges were compelled to abandon patent cases in order to prosecute criminal cases.

"At the present time, the inventor smart enough to obtain a patent on his development is king," says William Wesley, a patent attorney for Fermilab and the superconducting supercollider project in Texas. "More damage awards are routinely approved by the Federal Circuit Court of Appeals than ever before," he says.

**BUSINESS**

*"The pendulum has swung in favor of patent owners," says Fermilab's patent attorney William Wesley.*

But to protect a patent, a company often must file its application before product development is complete. This can lead to incomplete information, jeopardizing the patent's value.

Or worse. "When other people get the initial patent information, they can go to the next product development step or pursue alternatives quicker than you can," says Ronald Berenbeim of the Conference Board, a New York business group. □

## Productivity report stirs response from industry

MIT'S RECENT REPORT, "Made in America: Regaining the Productive Edge," has resulted in "a tremendous number of inquiries from industry and universities," says Michael Dertouzos, chairman of MIT's Commission on Industrial Productivity. Several companies and universities are already using the report as a basis for their own studies.

At MIT itself, the two-year-long study led to the creation in 1988 of the Leaders for Manufacturing program and a Lab for Manufacturing

### Poor foreign patent enforcement takes money from U.S. pockets

| Country | U.S. losses to foreign countries* |
|---|---|
| Taiwan | $752 |
| Mexico | 533 |
| Korea | 496 |
| Brazil | 426 |
| China | 420 |
| Canada | 367 |
| India | 244 |
| Japan | 192 |
| Nigeria | 158 |
| Hong Kong | 154 |
| Saudi Arabia | 131 |
| Indonesia | 130 |
| Italy | 110 |
| Spain | 103 |

*Millions of U.S. dollars
Source: Intl. Trade Commission

*Poor intellectual property protection cost 168 U.S. firms more than $4 billion in 1986.*

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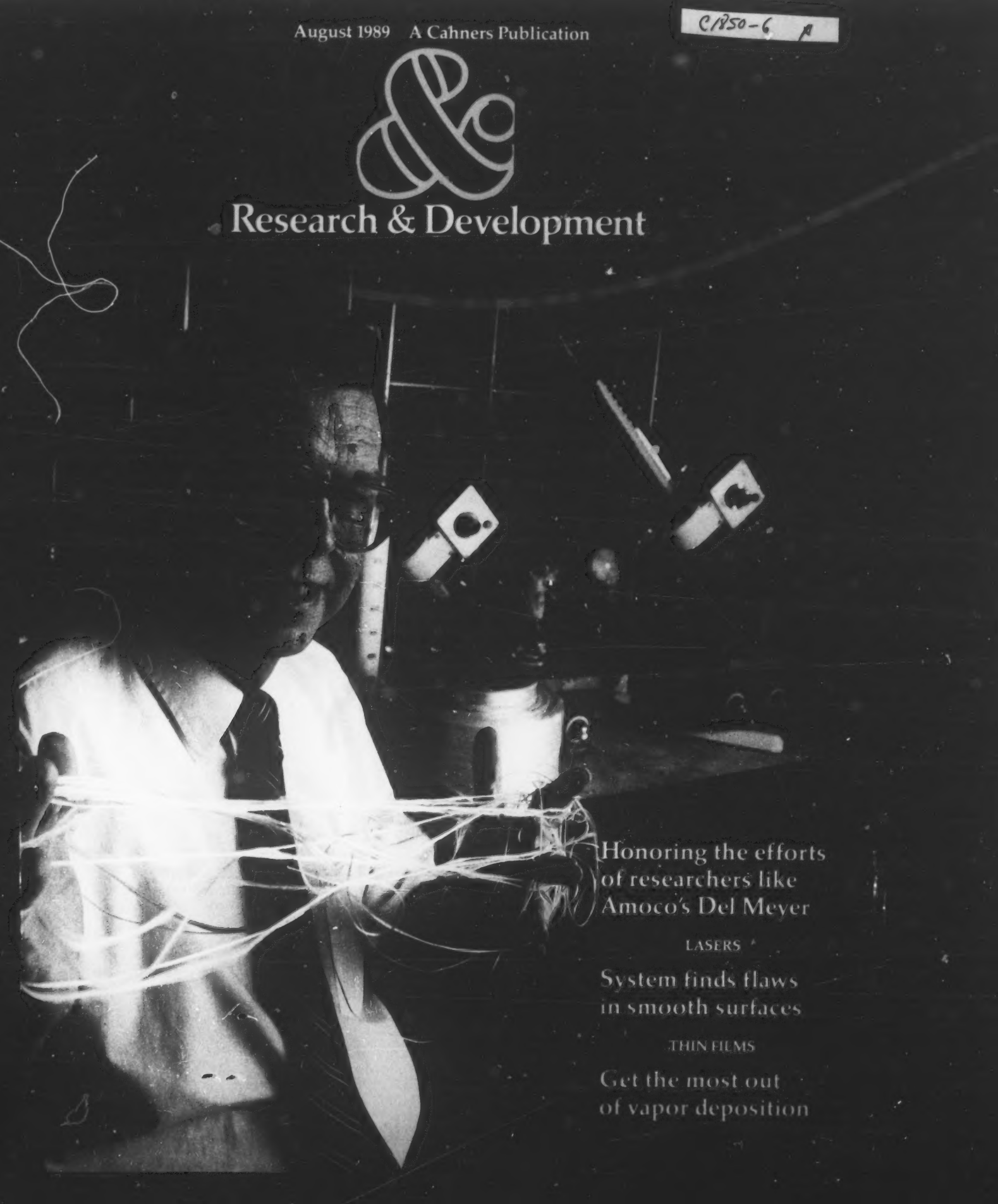
# Research & Development



Honoring the efforts of researchers like Amoco's Del Meyer

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System finds flaws in smooth surfaces

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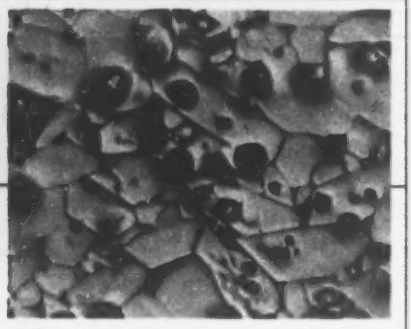

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# R&D

## BUSINESS

## Big companies are big R&D spenders

SPENDING for R&D is still rising for the biggest U.S. corporate researchers. In its annual survey, *Inside R&D* found that R&D spending increased 10.7% to $48.8 billion in 1988 for the top 100 spenders.

While mergers, buyouts, and restructurings may have slowed R&D investment by smaller companies, the 1988 increase exceeds that of 1987 by 6.4%.

The top 10 companies, which account for 44% ($21.6 billion) of the spending by the top 100, are the same companies as in the 1987 survey.

Of the top 100 spenders, the 3 companies with the largest R&D spending increases were Sun Microsystems (101.1%), Genentech (65.1%), and Prime Computer (58.9%). Companies that still made the top 100 list but which had significantly reduced their spending include Advanced Micro Devices (−15.9%), Perkin-Elmer (−14.7%), and Westinghouse Electric (−11.5%).

Minimum spending for getting on the list was $93 million, up from $81.5 million in 1987. □

## U.S. manufacturers get serious about lost semiconductor market

U.S. MANUFACTURERS took a significant step in late June toward bolstering their capabilities to compete in the world semiconductor market.

In an unprecedented decision, seven U.S. companies agreed to form U.S. Memories Inc., a joint venture to manufacture basic memory chips.

This venture presents interesting challenges to both Federal antitrust officials and Japanese memory manufacturers. To satisfy the U.S. Justice Dept., U.S. Memories will have to ensure that it is not a threat to existing U.S. competitors.

Both the Feds and the Japanese are closemouthed for the time being. They're waiting to see if Sanford Kane, president and CEO of the newly formed company, can really raise the $500 million he says is necessary to start the company. To take charge of U.S. Memories, Kane resigned his position as a vice president at IBM.

***U.S. Memories** president Sanford Kane says at least $500 million is needed from joint venture founders and other investors to start making 4-Mbit DRAMs.*

The seven companies that contributed $50,000 each to develop an initial business plan are IBM Corp., Digital Equipment Corp., Hewlett-Packard Co., Intel Corp., National Semiconductor Corp., Advanced Micro Devices Inc., and LSI Logic Corp.

The initial U.S. Memories product will be 4-Mbit dynamic random access memory (DRAM) chips. The design and manufacturing technology for these devices will be licensed from IBM. "By licensing IBM's design, U.S. Memories will have the jump start needed to quickly come on line as a serious player," said Gordon Moore, chairman of the Semiconductor Industry Assn. and chairman of Intel Corp.

While DRAM technology was invented in the U.S., Japanese competition drove all but Texas Instruments and Micron Technology out of the business (Motorola reentered the market earlier this year after agreeing to license Toshiba technology.)

Today, Japan's Toshiba Corp., NEC Corp., Mitsubishi Electric Corp., Hitachi Ltd., and Fujitsu Ltd. have 87% of the 1-Mbit DRAM world market. The U.S. has only 7%.

The world market for DRAMs is large, with $11 billion in sales expected in 1989 and $22 billion in 1993 according to Dataquest Inc., an industry analysis group. Profitability is high, with estimates of $2 billion in

### Top 10 U.S. spenders on R&D

| Rank 1988 | Rank 1987 | Company | R&D spending (billions of U.S. dollars) | Change from 1987 (%) |
|---|---|---|---|---|
| 1 | 1 | General Motors | 4.75 | 9.0 |
| 2 | 2 | IBM | 4.42 | 10.5 |
| 3 | 3 | Ford Motor | 2.93 | 16.5 |
| 4 | 4 | AT&T | 2.57 | 4.9 |
| 5 | 5 | DuPont | 1.32 | 7.9 |
| 6 | 7 | Digital Equipment | 1.31 | 29.3 |
| 7 | 6 | General Electric | 1.16 | 3.3 |
| 8 | 8 | Eastman Kodak | 1.15 | 15.6 |
| 9 | 9 | Hewlett-Packard | 1.02 | 13.1 |
| 10 | 10 | United Technologies | 0.93 | 6.1 |

Source: *Inside R&D*

***The top 10 U.S. companies that spent the most for R&D in 1988 are unchanged from 1987. These companies account for 44% of the R&D spending by the top 100 companies.***

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†Foreign

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# R&D

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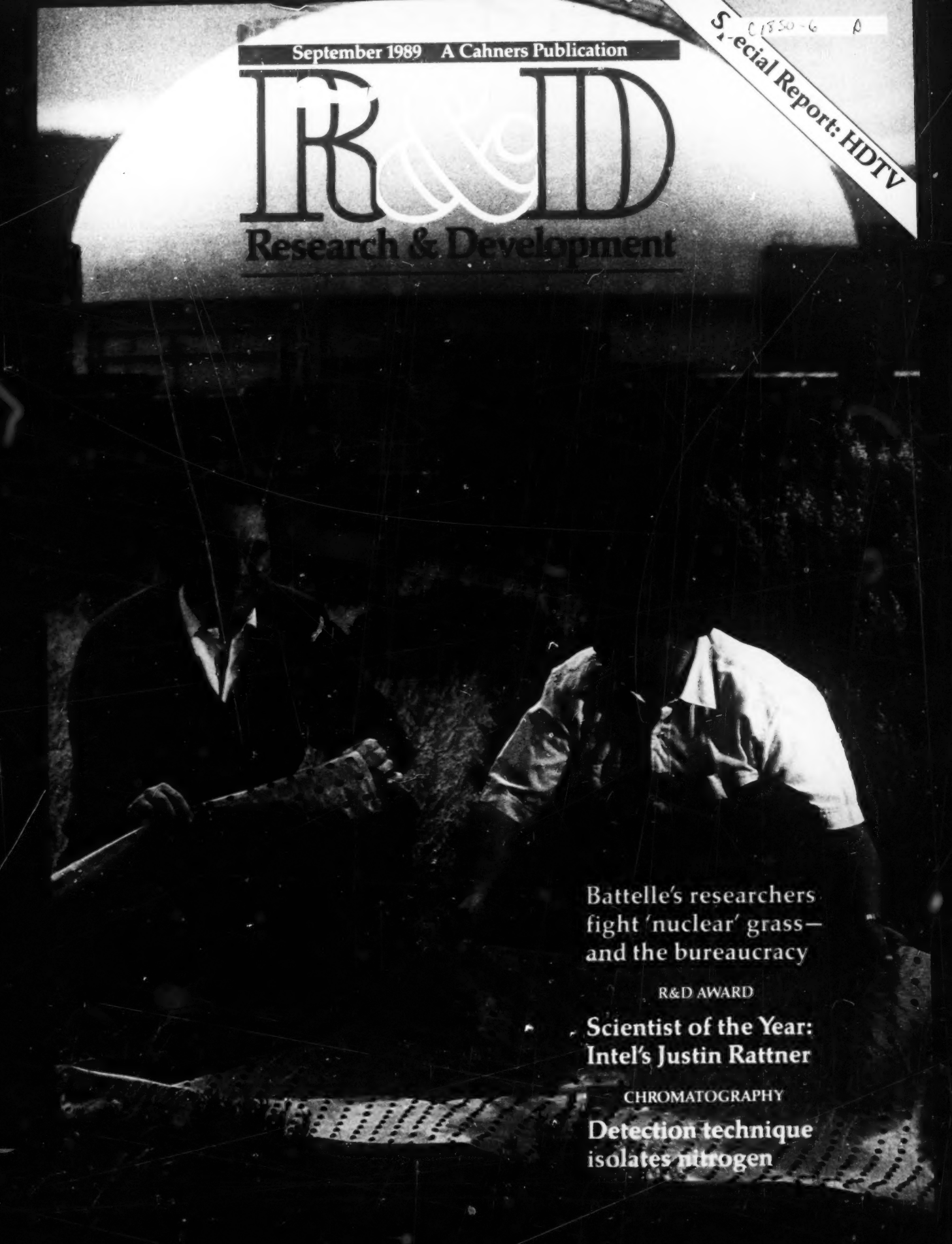

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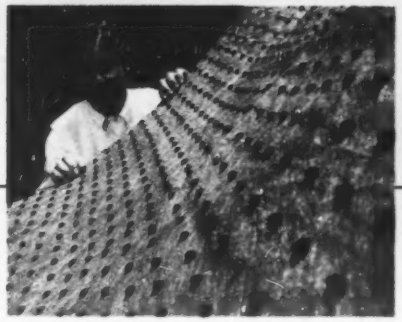

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## Mergers have little effect on R&D, experts say

LEVERAGED BUYOUTS (LBOs) and other corporate restructurings may have less impact on industry research spending than experts once believed, according to testimony given before a Congressional committee.

"The impact of actual takeovers is probably much smaller than that of high capital costs and competitive pressures, simply because manufacturers are more affected by stiff foreign competition than by actual takeover attempts," says Julie Fox Gorte, project director for the Office of Technology Assessment.

Gorte's testimony before the House science, research, and technology subcommittee concurred with that given by Bronwyn Hall, assistant professor of economics at Univ. of California–Berkeley.

"Manufacturing firms involved in acquisitions behave very much like other firms with respect to R&D—there is little sign of cuts which might be attributed to consolidation of laboratories or elimination of duplicative efforts after a merger," says Hall.

The premise that the huge debts incurred by companies during restructurings dramatically cuts into R&D investments has not been verified by studies performed by Gorte and Hall.

"In fact, restructurings may be a contributor to more-rapid technological change by hastening the downsizing and elimination of backward firms," says Hall.

Both experts conclude that no government intervention is required even though some companies have cut R&D to defend against takeovers. Polaroid, for example, cut R&D in response to a hostile takeover bid from Shamrock Holdings, and Owens-Corning cut R&D in half after a takeover attempt by Wickes.

The level of restructurings is significant, but not overwhelming, says Hall, and most have been concentrated in low-tech industries. "LBOs generally are not appropriate for high-tech businesses," she says.

"Since mergers and acquisitions are only part of the economic climate that discourages R&D, remedies are perhaps better directed against the short-sightedness presently fostered by financial markets and not against mergers and acquisitions," says Gorte.

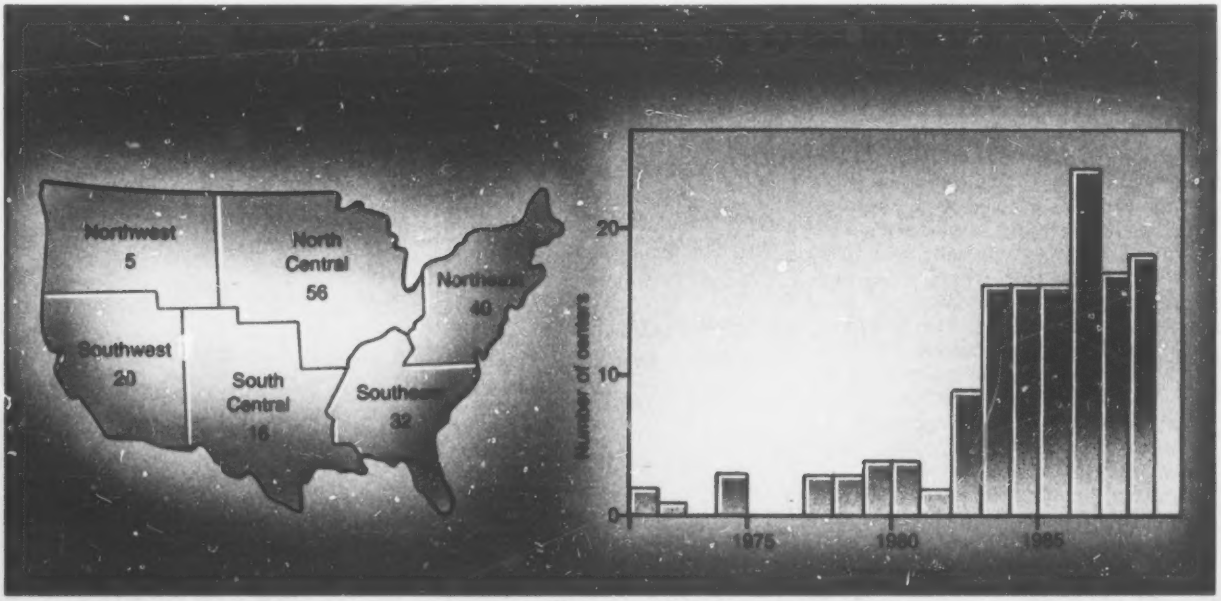
Both Hall and Gorte agree that the high real cost of investment monies for U.S. firms and the emphasis on short-term profits are much more damaging to long-term R&D levels than takeovers are. □

## Research centers bloom, but will the money last?

A NEW "Directory of Manufacturing Research Centers" reveals a dramatic growth of new centers over the past six years. Of the 169 centers listed in the directory, prepared by the Chicago-based Manufacturing Technology Information Analysis Center (MTIAC), 118, or 70%, have been started since 1983.

"The big question is how many of these centers are going to survive. Many have one to five years of seed money but, after that runs out, a lot may find their way into desk drawers," says Harold Wakely, who compiled the directory.

New centers seeking funds are finding that many industrial sources have already been tapped out. While some




*Of the 169 manufacturing research centers that exist in the United States, more than two thirds were started within the past six years. The map shows the number of centers in each of six geographical regions of the country.*

"hot" technologies may expand, there actually may be retrenchment in others that have less potential.

Nearly 70% of the existing centers are associated with university or technical institutes. However, many of the future centers started will be set up in community colleges. "You will see more of these types of centers and fewer basic research labs in the future," says Wakely.

For example, the Center for Occupational R&D (CORD), Waco, TX, is a consortium of more than 100 community colleges that is involved with the application of existing technologies and not research.

Government-funded centers will most likely receive increased funding. The National Institute of Standards & Technology already funds three centers—the Great Lakes Manufacturing Technology Center in Cleveland, the Northeast Manufacturing Center in Troy, NY, and the South Carolina Technology Cooperative in Columbia.

To be listed in MTIAC's directory, centers must perform manufacturing research and must be available to manufacturers on a free or fee basis. Cost of the directory is $75 for either hard copy or computer disk. For a copy call MTIAC at 312/567-4730. □

## Trade barriers continue to fall, but slowly

LICENSING REQUIREMENTS for the export of computers, communication equipment, and machine tools to Canada, 13 NATO members, Japan, Australia, Finland, and Switzerland have been removed by the U.S. Dept. of Commerce.

This action is viewed as a positive step by the Scientific Apparatus Makers Assn. (SAMA). "It will decontrol [the export and sale of] analytical instruments which have computer components," says Michael Duff, SAMA's vice president of government affairs.

"However, since the technological life of instrumentation is relatively short, the key to being competitive is to ensure that our trade controls mirror current products," says Duff.

Despite this liberalization, the 1988 Omnibus Trade Act still requires licensing for supercomputers and advanced mainframe computers to prevent these products from being shipped to Soviet-bloc countries.

A week after DOC loosened exporting requirements, the Administration allowed the sale of personal computers to Soviet-bloc nations. This action was quickly rebuked by the Defense Dept. as giving the Soviets products with military applications. □

## Top U.S. R&D spenders slip in world ranking

FOUR U.S. COMPANIES that were among the 10 biggest R&D spenders of 1988 will still be in the top 10 in 1990, but they will be lower on the totem pole.

That's because foreign-based firms will have leapfrogged them in research spending, according to a recent forecast by Schonfeld & Associates, an Evanston, IL, consulting firm.

General Motors and IBM will still be number one and two through 1990. But Ford will drop from fourth to fifth in the standings and AT&T will fall from sixth to ninth.

Japan's Matsushita (No. 4 in 1990), NEC (No. 6), and Toshiba (No. 7) and Europe's NV Philips (No. 8) all moved up in the two-year period.

The computer industry will become the biggest R&D spender in 1990 with $21.1 billion, up 11.5% from 1988, according to the forecast. This surpasses the lead now held by the communications industry, which will grow only 3.4% to $20.2 billion.

Both Japanese and European firms are forecast to have significant increases in R&D spending. While 13 of the top 25 spenders are U.S. based, their average increase in R&D spending is 7.9%. The 7 Japanese firms in the top 25 are expected to average a 14.4% increase, while the 5 European firms will increase on average 18.8%.

The report, "R&D Ratios & Budgets," ($295) lists 1988 to 1990 R&D data for more than 2,700 firms. To order, contact Schonfeld & Associates, 2530 Crawford Ave, Evanston, IL 60201; 312/869-5556. □

## Engineers pick the 10 best places to work

TO MAKE the Society of Manufacturing Engineers' 1989 list of the 10 best places to work in the U.S., a manufacturer has to involve researchers, engineers, and nontechnical staff in a team approach.

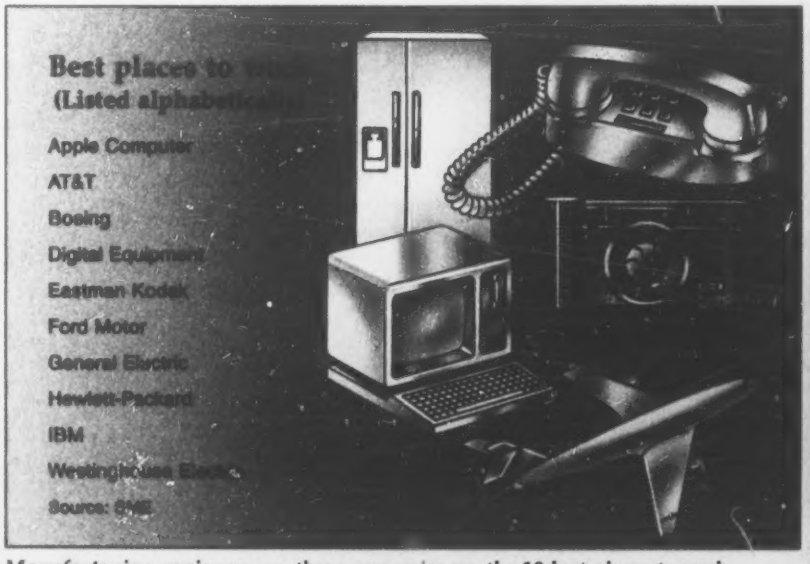
Companies were chosen by SME on the basis of their quality of supervision, commitment to high-quality products, and challenging, rewarding job opportunities.

"A successful program at AT&T allows R&D employes and manufacturing engineers to swap jobs for a six-month period," says Joan Redebaugh, co-author of the study.

"Technical people at Boeing can follow a technology [career] trail and have all the benefits of [being] on a management path," says SME's Robert Stauffer.

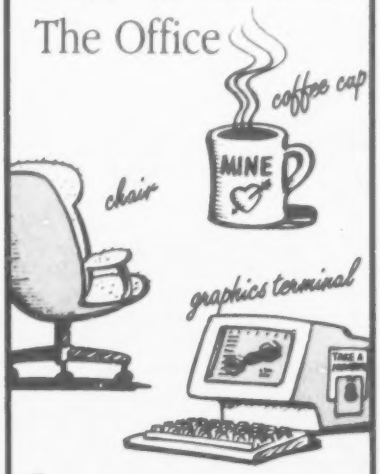
"We give our people a substantial amount of technical and intellectual freedom to do the right things," says Harold Edmondson, vice president of manufacturing at Hewlett-Packard.

Three of this year's winners—Apple, GE, and IBM—also won awards last year. **R&D**




*Manufacturing engineers say these companies are the 10 best places to work.*

## Three Things You Shouldn't Have To Share At The Office

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# R&D

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